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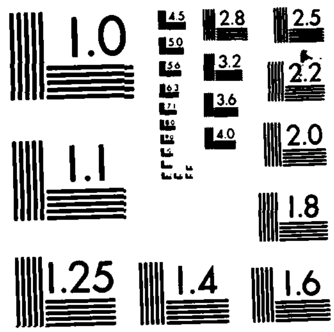

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EFFECT OF ANTENNA IMPEDANCE MISMATCH ON THE SIGNAL-TO-NOISE RATIO OF A RADIO RECEIVING SYSTEM

By

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REVIEW AND APPROVAL

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The noise factor of linear two-port networks are derived for several networks of interest, including those of a passive transmission line and of an active receiver, whose source impedance may be mismatched to the characteristic impedance of the line. It is shown that a large impedance mismatch at the antenna-transmission line interface of a radio receiving system can cause a significant increase in the system internal noise factor (more than a 50 dB increase for a voltage reflection coefficient of 0.999).

Numerical results are presented for a VHF-FM radio receiving system with an electrically-short monopole antenna. In the absence of a matching network, the limiting noise of the system is generated within the system (by the transmission line and receiver) and can be more than 20 dB larger than the external man-made noise. With a matching network, the limiting noise of the system is external man-made noise.

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19. continued Antenna impedance mismatch significantly affects the transmission line noise figure and to a lesser extent the receiver noise figure when the voltage reflection coefficient modulus $\gtrsim 0.5$ for a transmission line length equal to one free-space wavelength. However, for an external noise figure of 26 dB, the system operating noise figure is not significantly affected by antenna impedance mismatch until the voltage reflection coefficient modulus $\gtrsim 0.98$.

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The computer program SONF of the theoretical models for the System Operating Noise Figure was written by R. D. Parsons.

Measurements of the receiver parameters in Appendix III were performed by C. J. Beanland and A. E. Burns.

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SECTION I

The predection signal-to-noise ratio of radio receiving systems whose antennas are impedance matched to the transmission line between the receiver and the antenna is usually limited by receiver noise at frequencies above 100-200 MHz and by antenna external noise at frequencies below 100-200 MHz.(1),(2) However, when there is a large impedance mismatch at the antenna-transmission line interface, predetection signal-to-noise ratio can be significantly reduced because of decreased available signal power at the input to the receiver and increased noise factor of the receiver. Available power is defined as the power which would be delivered to a load if the load were set equal to the conjugate of the source impedance. Noise factor is a measure of the signal-to-noise ratio at the input to a linear two-port network relative to that at its output when the input available noise power is equal to the reference noise power.

The available signal power at the input to the receiver is a function of the transmission line efficiency. (The efficiency of a two-port network is defined as the ratio of the available powers at its output and input ports, respectively.) The efficiency of a transmission line is decreased by orders of magnitude, from that resulting from the ordinary exponential attenuation loss, when its characteristic impedance is appreciably different from its source impedance and the line is also sufficiently long with an attenuation coefficient greater than zero.(3)

The noise factor of the receiver, as in any linear two-port network, increases with increasing difference of its source impedance from its design source impedance (usually 50 ohms if fed

by a transmission line with 50 ohm characteristic impedance) for minimum noise factor[(4),(5)]. This property is a consequence of the equivalent circuit representation of any two-port network with internally-generated noise by a complex noise current generator and a complex noise voltage generator in parallel and series, respectively, with the noise-free two-port[(5)]. Consequently, a large impedance mismatch at the antenna-transmission line interface may cause the receiver's source impedance to be substantially diffferent from 50 ohms and consequently may cause an appreciably increased noise factor of the receiver.

The effect of antenna impedance mismatch on signal-to-noise ratio is of particular concern for radio receiving systems with electrically-small antennas. The transmission line usually has a nominal characteristic impedance of 50 ohms whereas an electrically-small antenna has a complex input impedance whose resistive component is much less than 50 ohms and whose reactive component is much greater than 50 ohms.

This paper investigates in detail the effects of antenna impedance mismatch on the signal-to-noise ratio of radio receiving systems. In Section 2, the theoretical model is developed with the assistance of Appendix I. Numerical results are given in Section 3 for a VHF-FM receiving system with an electrically-short monopole antenna. The numerical results are obtained from a computer program described in Appendices II-IV. The conclusions are given in Section 4.

SECTION 2

THEORETICAL MODEL

2.1 Margin Parameters of a Radio System

With reference to Figure 1 the predetection system margin $M(d,r_i)$ (in dB) of a radio system, for a propagation path distance d and message quality r_i, is given by

$$M(d,r_i) = \overbrace{P_T - L_{N,T} + G_T - L_b(d) + D_R}^{S(d)} - N - R_r(r_i) \qquad (1)$$

where

$S(d)$ = available signal power at the output terminals of the equivalent lossless receiving antenna (dBm)

P_T = transmitter carrier available output power (dBm)

$L_{N,T}$ = insertion loss of transmitter transmission line (including reflection losses, if any) (dB)

G_T = transmitter antenna gain (including ohmic losses of matching network, if any) (dB)

$L_b(d)$ = basic transmission loss of propagation path (dB)

D_R = directivity of the receiving antenna (dBi)

N = system available noise power referred to the output terminals of the equivalent lossless receiving antenna (dBm)

$R_r(r_i)$ = required predetection signal-to-noise ratio (dB)

The convention is followed that capitalized margin parameters are in units of dB whereas uncapitalized margin parameters refer to their numerical values. In Figure 1, the signal-to-noise ratio, referred to the output terminals of the equivalent lossless antenna, is equal to the receiver's predetection signal-to-noise ratio.

environmental noise in rural, residential, and business area locations. The system comprises a monopole antenna of 10 in. length and 1.4 in. diameter, a matching network solenoid of 1.5 in. length and 0.5 diameter, a P-I-N diode switch of 0.25 ohms series resistance, a 10 m length of RG-58/U coaxial transmission line, and a receiver with noise parameters $f_o = 5$ and $r_n = 100$ ohms.

The computer printouts of program SONF are given in Appendices IV A and IV B for the above case with and without a matching network, respectively.

The receiving system noise and available loss factors of Appendix IV are summarized in table 1. The modulus $|\Gamma_r|$ of the voltage reflection coefficient, at the transmission line-antenna interface looking in the direction of the antenna is $|\Gamma_r| =$ 0.9966-0.9991 without a matching network and $|\Gamma_r| = 0$ with a matching network over the frequency range 88-30 MHz. In the presence of a matching network, the system operating noise factor $\langle f \rangle$ is approximately equal to the antenna external noise factor $\langle f_a \rangle$. However, in the absence of a matching network, the system operating noise factor is appreciably larger than the antenna external noise because the product $f_r \ell_{n,r} \gg \langle f_a \rangle$ where f_r is the receiver noise factor and $\ell_{n,r}$ is the transmission line available loss factor. The factors f_r and $\ell_{n,r}$ are 2.7-4.5 and 132-6083 times larger, respectively, in the absence of a matching network than with a matching network over the frequency range 88 to 30 MHz. The large increase in the available loss factor $\ell_{n,r}$ implies a correspondingly large decrease in the available power efficiency of the transmission line [see Eq. (C-1) of Appendix I]. The efficiency, of a transmission line whose attenuation coefficient is non-zero, decreases significantly when its characteristic impedance is appreciably different from its source impedance and is also sufficiently long[3] [see Eq. (II-1) and Eq. (I-48) of Appendix I].

SECTION 3

NUMERICAL RESULTS FOR A VHF-FM RECEIVER WITH AN ELECTRICALLY-SHORT MONOPOLE ANTENNA

The effect of antenna impedance mismatch on the operating noise figure of a radio receiving system is numerically evaluated in this section for the case of a VHF-FM receiver with an electrically-short monopole antenna. For such a case, in the absence of a matching network, the real part of the antenna input impedance can be of the order of one ohm or less and the imaginary part can be of the order of several hundred ohms or more. Therefore, the antenna presents a large impedance mismatch to a 50 ohm transmission line. When matched, the VHF-FM receiving system is generally limited by external environmental noise which may be two or three orders of magnitude larger than receiver noise. Consequently, such a case is a severe test of the effect of antenna impedance mismatch on the system operating noise figure.

Numerical evaluation of the theoretical model of Section 2 for the above case was facilitated by the MITRE computer program SONF (System Operating Noise Figure) described in Appendix II. A description of the program including tables of input variables, constants, derived output variables, and numerical values of the input variables are given in Appendix IIA. The program files and listing are given in Appendices IIB and IIC, respectively.

Numerical values of the table II-4 input parameters to program SONF are derived in Appendix III for the case of a VHF-FM receiving system with an electrically-short monopole antenna. Numerical values are calculated at 30, 50, and 88 MHz for man-made

The receiver noise factor f_r has a minimum value f_o for a source admittance $y_s = y_{no}$. Most receivers are designed to have a minimum noise factor f_o for a source admittance $y_s = 1/\ \mathrm{Re}(z_{or})$. For such a condition,

$$\left.\begin{aligned} g_{no} &= 1/\mathrm{Re}(z_{or}) \\ b_{no} &= 0 \end{aligned}\right\} ,\ f_r = f_o \text{ for } y_s = 1/\mathrm{Re}(z_{or}) \qquad (26)$$

For the conditions of Eq. (26), the receiver input impedance is generally not matched to the characteristic impedance of the transmission line.

For the conditions of Eq. (26) and with reference to Eqs. (24) and (25), the receiver noise factor f_r increases with increasing impedance mismatch of the antenna to the transmission line.

For $|\Gamma_r| = 0$, $f_r = f_o$ whereas for $|\Gamma_r| = 1$, $f_o \leq f_r < \infty$. In particular for the case $|\Gamma_r| = 1$,

$$\lim f_r = \begin{cases} f_o, & \alpha_r d_r \longrightarrow \infty \\ \infty, & \gamma_r d_r \longrightarrow 0 \end{cases} ,\ |\Gamma_r| = 1 \qquad (27)$$

2.5 Receiver noise factor

The receiver noise factor f_r is a function of the source admittance y_s seen by the receiver looking back at the transmission line (see fig. 2) and consequently is a function of antenna impedance mismatch. The source admittance y_s is given by

$$y_s = \frac{1}{z_{or}} \frac{1 - \Gamma_r \exp(-2\gamma_r d_r)}{1 + \Gamma_r \exp(-2\gamma_r d_r)} \qquad (24)$$

where z_{or}, Γ_r, γ_r, and d_r are defined in fig 2.

The receiver noise factor f_r, for an arbitrary source admittance y_s at an ambient temperature equal to the reference temperature t_{ref}, is given by Eq. (I-53) of Appendix IE as

$$f_r = f_o + \frac{r_n}{\mathrm{Re}(y_s)} \left| y_s - y_{no} \right|^2 \qquad (25)$$

where

f_o = minimum noise factor of receiver for any possible source admittance y_s at an ambient temperature equal to the reference temperature t_{ref}.

$y_{no} = g_{no} + jb_{no}$ = complex empirical receiver noise parameter with the dimensions of admittance (mhos).

r_n = empirical receiver noise parameter with the dimensions of resistance which accounts for the sensitivity of the receiver noise factor to receiver source impedance (ohms).

The voltage reflection coefficient Γ_r is given by

$$\Gamma_r = (z_r - z_{or})/(z_r + z_{or}) \tag{20}$$

The input impedance z_r to the antenna circuit, including the matching network, is given by

$$z_r = a^2 [(r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r}) + j(x_{a,r} + x_{m,r})]$$
$$= \begin{cases} z_{or}, & \text{antenna conjugate-matched to transmission line} \\ r_{a,r} + r_{c,r} + j\, x_{a,r}, & \text{no matching network} \end{cases} \tag{21}$$

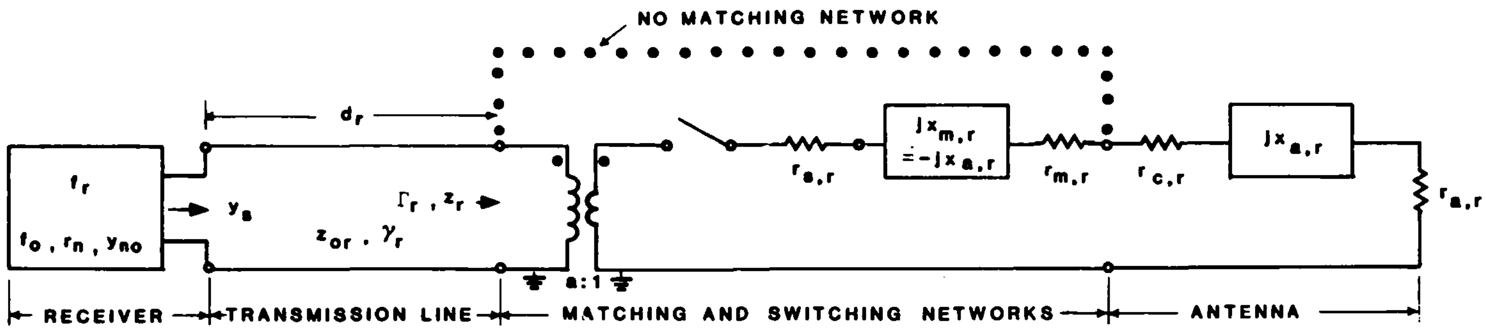
When the antenna is conjugate impedance matched ($\Gamma_r = 0$) to a transmission line by the matching network, then the matching network parameters $x_{m,r}$ and a are given by

$$\left.\begin{aligned} x_{m,r} &= - x_{a,r} + (1/a^2)\ \mathrm{Im}(z_{or}) \\ a &= [\mathrm{Re}(z_{or})/(r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r})]^{1/2} \end{aligned}\right\}, \quad \Gamma_r = 0 \tag{22}$$

In the absence of any matching network,

$$\left.\begin{aligned} x_{m,r} &= 0 = r_{m,r} = r_{s,r} \\ a &= 1. \end{aligned}\right\}, \text{ no matching network} \tag{23}$$

The antenna available loss factor $\ell_{a,r}$ in Eq. (17) is not a function of antenna impedance mismatch. The matching network available loss factor $\ell_{m,r}$ in Eq. (18) is an indirect function of antenna impedance mismatch since the presence or absence of a matching network is a consequence of impedance mismatch. The transmission line available loss factor in Eq. (19) is a direct function of antenna impedance mismatch.



NOTE: LEAKAGE FLUX OF TRANSFORMER IS NOT CONSIDERED IN ABOVE CIRCUITS

$r_{a,r}$=ANTENNA RADIATION RESISTANCE

$r_{c,r}$=ANTENNA OHMIC RESISTANCE

$x_{a,r}$=ANTENNA REACTANCE

$z_{o,r}$=CHARACTERISTIC IMPEDANCE OF TRANSMISSION LINE

γ_r=PROPAGATION CONSTANT OF TRANSMISSION LINE

$r_{m,r}$=MATCHING NETWORK RESISTANCE

y_s=SOURCE ADMITTANCE TO RECEIVER

f_r=RECEIVER NOISE FACTOR

$x_{m,r}$=MATCHING NETWORK REACTANCE

a =TRANSFORMER TURNS RATIO

$r_{s,r}$=SWITCH OHMIC RESISTANCE

Γ_r=VOLTAGE REFLECTION COEFFICIENT AT MATCHING NETWORK

z_r=INPUT IMPEDANCE TO MATCHING NETWORK

d_r=LENGTH OF TRANSMISSION LINE

f_o=RECEIVER MINIMUM NOISE FACTOR

r_n=EMPIRICAL RECEIVER NOISE PARAMETER

y_{no}=COMPLEX EMPIRICAL RECEIVER NOISE PARAMETER

Figure 2. Impedance Equivalent Circuit of Receiving System

2.4 Available loss factors

The available loss factor of a passive linear two-port network is the reciprocal of the available power efficiency of the network (see Eq. I-22). With reference to fig. 2 and Eq. (I-70), Eq. (I-71), and Eq. (I-72) of Appendix IH, the receiving system available loss factors $\ell_{c,r}$, $\ell_{m,r}$, $\ell_{n,r}$ of the antenna, matching network, and transmission line, respectively, are given by

$$\ell_{c,r} = 1 + (r_{c,r}/r_{a,r}) \tag{17}$$

$$\ell_{m,r} = 1 + [(r_{m,r} + r_{s,r})/(r_{a,r} + r_{c,r})] \tag{18}$$

$$\ell_{n,r} = \frac{\exp(2\alpha_r d_r)\left\{1 - |\Gamma_r|^2 \exp(-4\alpha_r d_r) - 2\left[\mathrm{Im}(z_{or})/\mathrm{Re}(z_{or})\right] \mathrm{Im}\left[\Gamma_r \exp(-2\gamma_r d_r)\right]\right\}}{1 - |\Gamma_r|^2 - 2\left[\mathrm{Im}(z_{or})/\mathrm{Re}(z_{or})\right] \mathrm{Im}(\Gamma_r)} \tag{19}$$

where $r_{a,r}$, $r_{c,r}$, $r_{m,r}$, $r_{s,r}$, z_{or}), $\gamma_r = \alpha_r + j\beta_r$, d_r, Γ_r, and z_r are circuit parameters defined in fig. 2 of the impedance equivalent circuit of the receiving system. The redundant subscript r of these parameters denotes receiving system and distinguishes them from their transmitting system counterparts in fig. 1.

In Eq. (19) the transmission line available loss factor $\ell_{n,r}$ increases with increasing modulus of the voltage reflection coefficient at the antenna transmission line interface. For $|\Gamma_r| = 0$, $\ell_{n,r} = \exp(2\alpha_r d_r)$. For $\Gamma_r = 1$,

$$\ell_{n,r} = \begin{cases} \infty, & \gamma_r d_r \neq 0 \\ 1, & \gamma_r d_r \to 0 \end{cases}$$

where

$d_r(\theta,\phi)$ = receiver directive gain in the elevation and azimuthal directions θ and ϕ, respectively (numeric)

$f_a(\theta,\phi)$ = antenna noise factor in the elevation and azimuthal directions θ and ϕ, respectively (numeric)

The expected value and standard deviation of the antenna external noise factor f_a are related to those of the antenna external noise figure F_a by Eq. (10) and Eq. (11). Empirical data of the expected value $\langle F_a \rangle$ at HF and VHF frequencies for man-made environmental noise relative to that of a thermal source at 288 deg K are plotted in figure III-4 of Appendix IIIG.

The standard deviation σ_{F_a} of the antenna external noise figure is related to standard deviations of the time and location variabilities $\sigma_{F_{a,t}}$ and σ_{F_a}, by Eq. (10) of table II-3 in Appendix II A. The time variability $\sigma_{F_{a,t}}$ is a function of the time variability upper and lower deciles, $D_{u,F_{a,t}}$ and $D_{\ell,F_{a,t}}$, respectively, given by Eq. (9) of table II-3 in Appendix IIA. Empirical data and extrapolations of $\sigma_{F_{a,t}}$, $D_{u,F_{a,t}}$, and $D_{\ell,F_{a,t}}$ at HF and VHF frequencies for man-made environmental noise are given in table III-1 through table III-4 of Appendix III G.

The parameters $\langle F_a \rangle$ and σ_F are not a function of antenna impedance and consequently are not a function of antenna impedance mismatch.

The noise degradation figure ΔF is the system operating noise figure relative to the antenna external noise figure and is a measure of the contribution of the internal noise sources to the system operating noise figure. The expected value $\langle F \rangle$ is given by

$$\langle \Delta F \rangle = \langle F \rangle - \langle F_a \rangle \quad \text{(dB)} \tag{15}$$

where $\langle F \rangle$ is given by Eq. (12).

In Eq. (14), ΔF is a function of both the external noise figure F_a and the system operating noise figure F.

The noise figure F is a function of the external antenna noise factor f_a; the available loss factors $\ell_{c,r}$, $\ell_{m,r}$, $\ell_{n,r}$, and the receiver noise factor f_r. Expressions for each of these factors now follow. It will be seen that only the factors $\ell_{m,r}$, $\ell_{n,r}$, and f_r are functions of the impedance mismatch of the receiving antenna to the receiving transmission line.

2.3 Antenna External Noise Factor

The external noise, which is incident on the receiving antenna within a differential solid angle at an elevation angle θ and azimuthal angle ϕ(see figure 1), must be integrated over the entire sphere of the antenna's directional gain pattern to obtain the total external noise at the output terminals of the equivalent lossless antenna. Accordingly, the external noise factor f_a is given by

$$f_a = \int_0^{2\pi} \int_{-\pi/2}^{\pi/2} f_a(\theta,\phi) \; d_r(\theta,\phi) \, \sin\theta \, d\theta \, d\phi \tag{16}$$

When man-made noise is the dominant noise source, F_a (in dB) is approximately two-piecewise normally distributed with a breakpoint at the median value.[2] Nevertheless, if the external noise F_a is assumed to be approximately normally distributed, then from Eq. (9), the external noise factor f_a is lognormally distributed. For such distributions the expected values and standard deviations of the two distributions are related by [6]

$$\langle f_a \rangle = 10^{[(\langle F_a \rangle/10) + \frac{1}{2}\ell n 10\,(\sigma_{F_a}/10)^2]} \tag{10}$$

$$\sigma_{f_a} = \langle f_a \rangle \cdot \left[10^{\ell n 10\,(\sigma_{F_a}/10)^2} - 1\right]^{1/2} \tag{11}$$

Similarly, if the operating noise factor f is assumed to be approximately lognormally distributed, then from Eq. (4), the operating noise figure F is normally distributed. For such distributions, the expected values and standard deviations of the two distributions are related by

$$\langle F \rangle = 10\,[\log_{10}\langle f \rangle - \frac{1}{2}\ell n 10\,(\sigma_F/10)^2] \tag{12}$$

$$\sigma_F = 10\left\{(1/\ell n 10)\log_{10}[1 + (\sigma_f/\langle f \rangle)^2]\right\}^{1/2} \tag{13}$$

where $\langle f \rangle$ and σ_f are given by Eqs. (7) and (8).

For the purpose of distinguishing between external and internal noise, it is useful to define a receiving system noise degradation figure ΔF (in dB) by

$$\Delta F \equiv F_a - F \qquad \text{(dB)} \tag{14}$$

If the ambient temperatures of the antenna, matching network, and transmission line are equal to the reference temperature t_{ref}, then Eq. (5) reduces to

$$f = f_a - 1 + \ell_{c,r}\ell_{m,r}\ell_{n,r}f_r, \quad t_c = t_m = t_n = t_{ref} \tag{6}$$

In the present study, the parameters of Eq. (5) will be treated as deterministic quantities with the exception of the antenna external noise factor f_a which shall be treated as a stochastic variable. Examples of stochastic external noise sources are the atmosphere and man-made environment such as power lines and automobile ignitions.

The expected value $\langle f \rangle$ and standard deviation σ_f of the operating noise factor f are therefore given by

$$f = \langle f_a \rangle + (\ell_{c,r} - 1)(t_c/t_{ref}) + \ell_{c,r}(\ell_{m,r} - 1)(t_m/t_{ref}) + \ell_{c,r}\ell_{m,r}(\ell_{n,r} - 1)(t_n/t_{ref}) + \ell_{c,r}\ell_{m,r}\ell_{n,r}(f_r - 1) \tag{7}$$

$$\sigma_f = \sigma_{f_a} \tag{8}$$

where $\langle f_a \rangle$ and σ_{f_a} are the expected value and standard deviation, respectively, of the external noise factor f_a.

The external noise factor f_a is related by definition to the external noise figure F_a (in dB) by

$$f_a \equiv 10^{(F_a/10)}, \quad F_a \equiv 10 \log_{10} f_a \tag{9}$$

It is convenient to set t_{ref} = 288 deg K because measurements of atmospheric noise and man-made environmental noise are usually referenced to thermal noise at that temperature and because $10 \log_{10} kt_{ref} = -204.0059$ dBj is approximately a whole number [1].

The system operating noise figure F may be expressed as

$$F = 10 \log_{10} f \tag{4}$$

where

$f = t_a/t_{ref}$ = system operating noise factor (deg/deg)

t_a = effective system noise temperature (deg K)

With reference to fig. 1 and Eq. (I-66) of Appendix IH, the system operating noise factor f is given by

$$f = f_a + (\ell_{c,r} - 1)(t_c/t_{ref}) + \ell_{c,r}(\ell_{m,r} - 1)(t_m/t_{ref}) + \ell_{c,r}\ell_{m,r}(\ell_{n,r} - 1)(t_n/t_{ref}) + \ell_{c,r}\ell_{m,r}\ell_{n,r}(f_r - 1) \tag{5}$$

where

f_a = receiving antenna external noise factor integrated over the antenna pattern function (deg/deg)

$\ell_{c,r}, \ell_{m,r}, \ell_{n,r}$ = available loss factors of the receiving antenna, matching network, and transmission line, respectively (deg/deg)

t_c, t_m, t_n = ambient temperatures of the receiving antenna, matching network, and transmission line, respectively (deg K)

f_r = receiver noise factor (deg/deg)

2.2 System Operating Noise Figure

The system available noise power N in Eq. (1) referred to the output terminals of the equivalent lossless receiving antenna (see Fig. 1), is the time-averaged power, contributed by all noise sources both internal and external to the receiver system, that would be delivered by the lossless antenna to a load if the load impedance were set equal to the conjugate output impedance of the lossless antenna. Examples of external noise sources are the atmosphere, stars, man-made environment (power lines, automobile ignition systems, etc.), and jammers both hostile and friendly. Internal noise sources are the receiver, antenna, antenna matching network, and transmission line of the receiving system.

The system available noise power N (in dBm) may be expressed as:

$$N = W + F \tag{2}$$

where

W = system reference noise power (dBm)

F = system operating noise figure, referenced to W (dB)

The system reference noise power W is given by

$$W = 30 + 10 \log_{10} (kt_{ref}b) \quad \text{(dBm)} \tag{3}$$

where

k = Boltzmann's constant = 1.38×10^{-23} J/deg K

t_{ref} = reference noise temperature = 288 deg K

b = receiver noise power effective bandwidth (Hz)

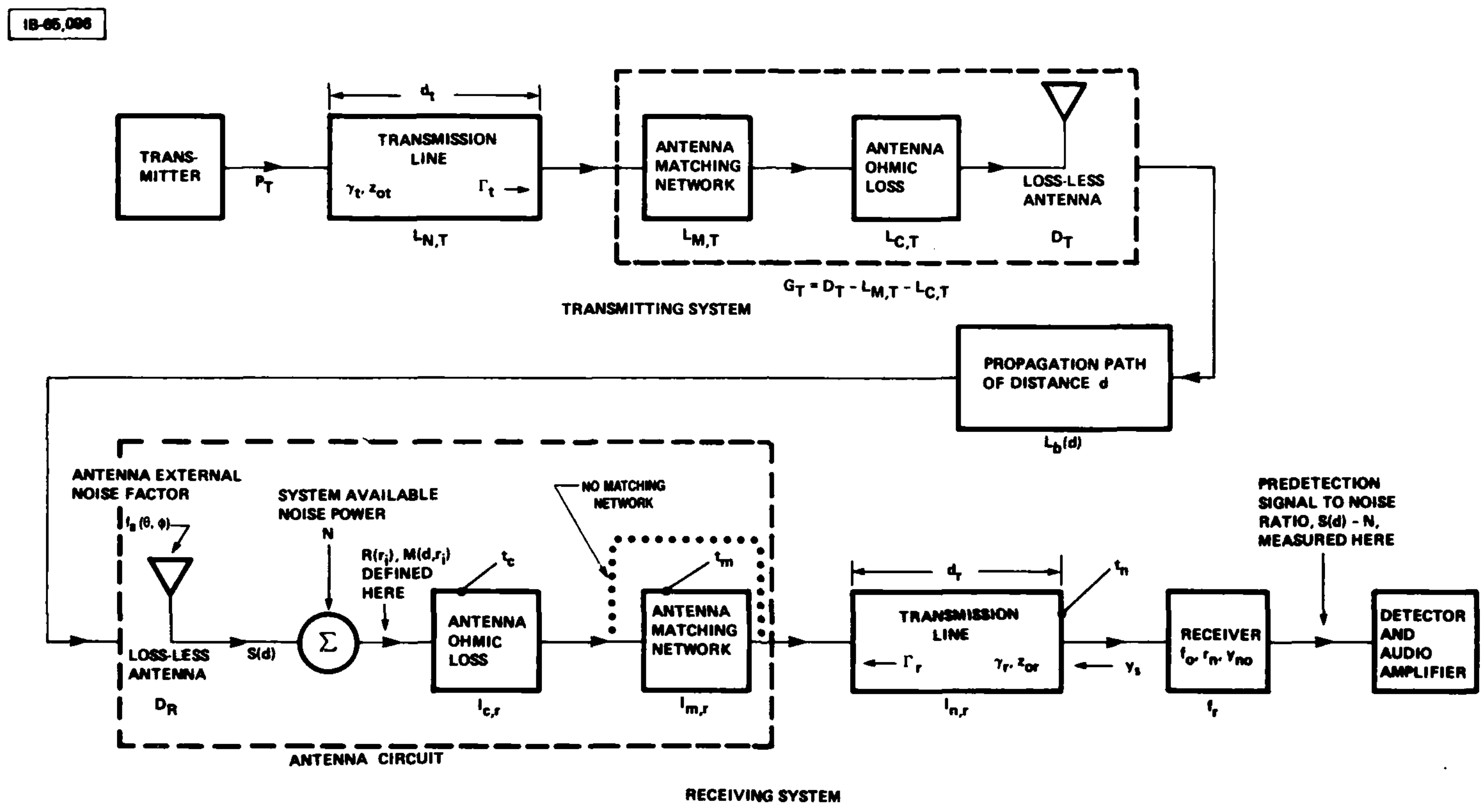


Figure 1. System Margin Parameters of Radio System

Table 1. Noise Parameter Factors for a Receiving System with an Electrically-Short Monopole Antenna

Antenna: 10" Monopole 1.4 in. Diameter
Matching Network: Coil, 0.5 in. Diameter, Single-Layer, 1.5 in Length
Switch: P-I-N Diode, 0.25 ohms Resistance
Transmission Line: RG-58 Coaxial Line, 10m Length
Receiver: f_o=5, r_n=100 ohms

With or Without Matching Network	Frequency (MHz)	Man-Made Noise Location	Noise Factor (Relative to 288 deg K Thermal Noise): System Operating $\langle f \rangle$	Antenna External $\langle f_a \rangle$	Receiver f_r	Available Loss Factors: Antenna ohmic $\ell_{c,r}$	Matching Network $\ell_{m,r}$	Transmission Line $\ell_{n,r}$	Voltage Reflection Coefficient $\lvert\Gamma_r\rvert$
Without	30	Business	209400.0	41860.0	22.71	1.004	1.0	7348.0	0.9991
		Residential	176600.0	9106.0	22.71	1.004	1.0	7348.0	
		Rural	168600.0	1096.0	22.71	1.004	1.0	7348.0	
	50	Business	42990.0	20560.0	17.81	1.002	1.0	1257.0	0.9986
		Residential	24920.0	2488.0	17.81	1.002	1.0	1257.0	
		Rural	22600.0	1720.0	17.81	1.002	1.0	1257.0	
	88	Business	5016.0	2551.0	13.44	1.001	1.0	183.4	0.9966
		Residential	2831.0	366.4	13.44	1.001	1.0	183.4	
		Rural	2515.0	49.9	13.44	1.001	1.0	183.4	
With	30	Business	41940.0	41860.0	5.03	1.004	12.88	1.208	0
		Residential	9184.0	9106.0	5.03	1.004	12.88	1.208	
		Rural	1174.0	1096.0	5.03	1.004	12.88	1.208	
	50	Business	20580.0	20560.0	5.03	1.002	3.18	1.278	0
		Residential	2507.0	2488.0	5.03	1.002	3.18	1.278	
		Rural	1915.0	1720.0	5.03	1.002	3.18	1.278	
	88	Business	2559.0	2551.0	5.03	1.001	1.367	1.39	0
		Residential	375.0	366.4	5.03	1.001	1.367	1.39	
		Rural	58.5	49.9	5.03	1.001	1.367	1.39	

$$\langle f \rangle = \langle f_a \rangle - 1 + \ell_{c,n}\, \ell_{m,r}\, \ell_{n,r}\, f_r$$

The numerical values of the system noise degradation figure in Appendix IV are summarized in table 2. The system noise degradation figure $\langle \Delta F \rangle$ is 26.0-5.8 dB without a matching network and 1.23-0.01 dB with a matching network over the entire range of frequencies (30-88 MHz) and external man-made noise environments (rural, residential, and business areas). In the absence of a matching network, the noise degradation figure decreases with increasing man-made noise and increasing frequency because ΔF is defined relative to man-made noise and because both man-made noise and $|\Gamma_r|$ decreases with increasing frequency.

The main conclusion to be drawn from tables 1 and 2 is that the system internal noise factor is small with respect to the external noise factor when the electrically-short receiving antenna is matched to the transmsission line but is large when the antenna is not matched.

The above results were for a transmission line whose length was at least one free-space wavelength. The effect of transmission line length on the noise figures of the transmission line and receiver at 30 MHz is shown in figure 3. The computer printouts are given in Appendix IVC. For a large mismatch of the antenna impedance to the transmission line, the combined noise figure of the transmission line and receiver remains large regardless of line length. Smaller line lengths result in a smaller transmission-line noise figure (because of less ohmic loss) but a larger receiver noise figure (because of less padding by the transmission line of the antenna impedance mismatch). When the antenna impedance is matched to the transmission line, the transmission line noise figure is limited to that resulting from the ordinary exponential attenuation loss of the transmission line. For arbitrary values of the receiver noise parameter r_n, there exists a line length for which the combined noise figure of the transmission line and receiver is minimized. In figure 3, it is fortuitous for r_n=100 ohms that the combined noise figure is approximately independent of line length for line lengths less than 0.1 wavelength.

Table 2. System Noise Degradation Figure for a Receiving System with an Electrically-Short Monopole Antenna

FREQUENCY f (MHz)	EXPECTED VALUE OF NOISE DEGRADATION FIGURE, $\langle \Delta F \rangle = \langle F \rangle - \langle F_a \rangle$ (dB)					
	WITH MATCHING NETWORK			NO MATCHING NETWORK		
	RURAL	RESIDENTIAL	BUSINESS	RURAL	RESIDENTIAL	BUSINESS
30	0.547	0.073	0.016	26.0	20.7	13.6
50	0.753	0.067	0.008	23.4	17.6	6.4
88	1.229	0.197	0.029	20.7	15.1	5.8

ANTENNA: 10" Monopole, 1.4 in. Diameter

MATCHING NETWORK: Coil, 0.5 in. Diameter, Single Layer, 1.5 in. Length

SWITCH: P-I-N Diode, 0.25 Ohms Resistance

TRANSMISSION LINE: RG-58/U Coaxial Line, 10m Length

RECEIVER: $f_o=5$, $r_n=100$ Ohms

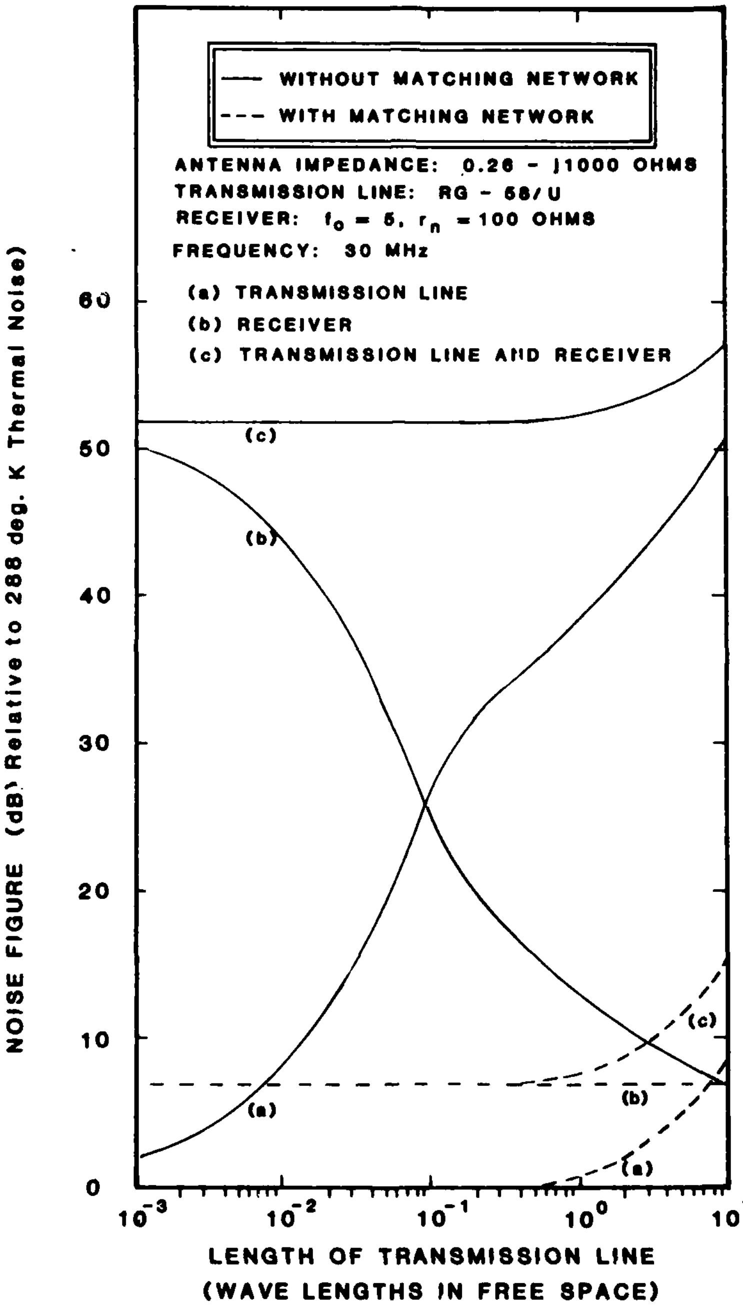


Figure 3. Transmission Line and Receiver Noise Figures Vs. Transmission Line Length

SECTION 4

CONCLUSIONS

A large impedance mismatch at the antenna-transmission line interface of a radio receiving system can cause a significant increase in the system internal noise factor (more than a 50 dB increase for a voltage reflection coefficient of 0.999).

This conclusion is supported by numerical results for a VHF-FM radio receiving system with an electrically-short monopole antenna. In the absence of a matching network, the limiting noise of the system is generated within the system (by the transmission line and receiver) and can be more than 20 dB larger than the external man-made noise. With a matching network, the limiting noise of the system is external man-made noise.

Antenna impedance mismatch significantly affects the transmission line noise figure and to a lesser extent the receiver noise figure when the voltage reflection coefficient $|\Gamma_R| \gtrsim 0.5$ as illustrated in figure 4 for a transmission line length of 10 m at 30 MHz. However, for an antenna external noise figure of 26 dB, the system operating noise figure is not significantly affected by antenna impedance mismatch until the voltage reflection coefficient $|\Gamma_r| \gtrsim 0.98$.

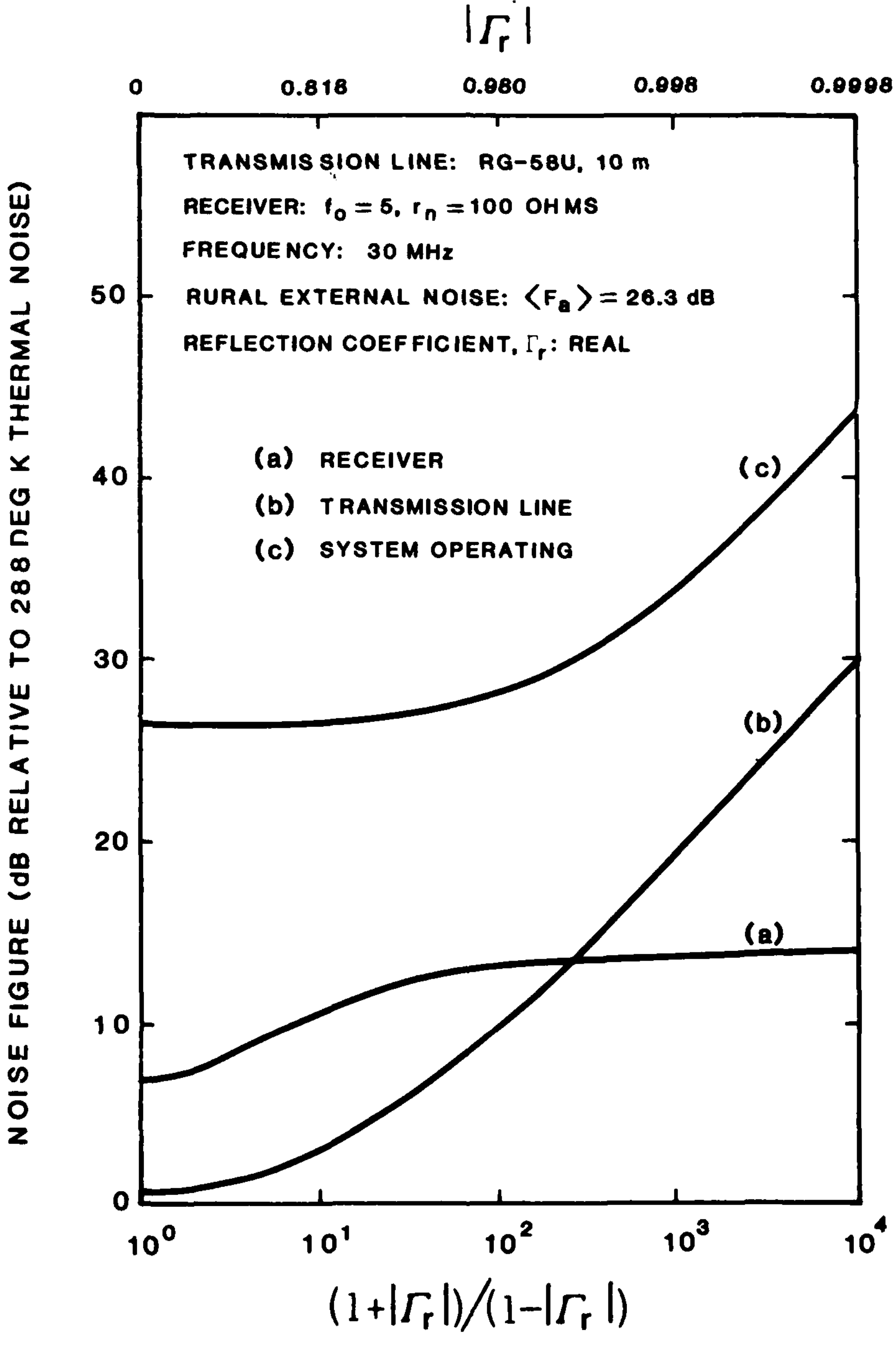


Figure 4. Effect of Voltage Reflection Coefficient $|\Gamma_R|$ on Noise Figure.

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4. H. A. Haus et al "IRE Standards on Methods of Measuring Noise in Linear Two-Ports, 1959, Proceedings of the Institute of Radio Engineers (IRE), Vol. 48, pp. 61-68, January, 1960.

5. H. A. Haus, et al, "Representation of Noise in Linear Two-Ports," Proc. of the IRE, Vol. 48, pp. 69-74, January 1960.

6. J. Aitchison and J. Brown, "The Lognormal Distribution," (Cambridge University Press, Cambridge, England, 1969), p. 8 Eqs. (2.7)-(2.9). When the lognormal distribution is expressed in logarithms to the base 10 instead of to the base e, then Eqs. (2.7)-(2.9) are modified to a form given by Eqs. (10)-(13) in Section 2 of the present paper.

APPENDIX I

NOISE FACTOR OF LINEAR TWO-PORT NETWORKS

CONTENTS

I.A Definitions

With reference to figure I-1(a), consider a linear two-port network, which may be passive or active, at an ambient temperature t_n (deg K), with an effective (ideal square-top) bandwidth b (Hz), input and output impedances Z_{in} and Z_{out} (ohms), respectively, a load impedance Z_L, and a CW source generator with open-circuited signal voltage $v_g = \mathrm{Re}(V_g e^{j\omega t})$ (volts) and source impedance Z_g at an ambient temperature t_g equal to the reference noise temperature $t_{ref} \equiv n_{ref}/kb$ where n_{ref} = reference noise power (W) and k = Boltzmann's constant = 1.38×10^{-23} (J/deg K). It is often convenient to choose n_{ref} such that $t_{ref} = 288^o$ deg K for the reasons stated in section 2.2.

The noise factor f_n of the linear two port is defined as[1]

$$f_n = (s_i/n_{ref})/(s_o/n_o) \ , \ t_g = t_{ref} \qquad \text{(I-1)}$$

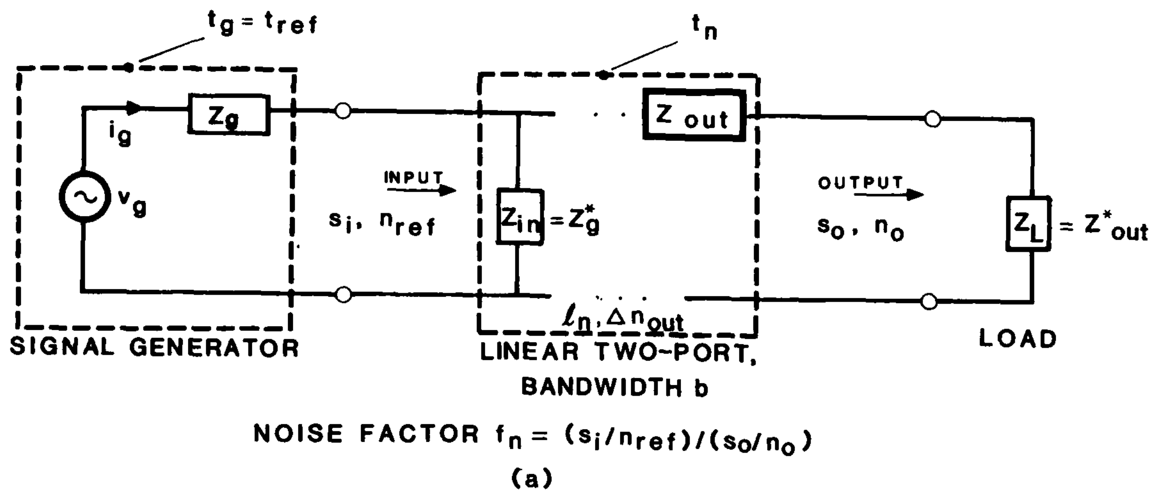
where

$$s_i = \overline{(v_g/2)\ i_g} = (1/2)\ \mathrm{Re}\left[(V_g/2)\ I_g^*\right] = (1/2)\ \mathrm{Re}\left\{(V_g/2)\left[V_g/(Z_g+Z_g^*)\right]^*\right\}$$

$= |V_g|^2/8\ \mathrm{Re}(Z_g)$ = available input signal power at the input terminals to the two-port (W). The bar indicates that the signal power is time-averaged over a cycle. The star indicates the complex conjugate of the parameter. The current $i_g = \mathrm{Re}\ (I_g\ e^{j\omega t})$ $= \mathrm{Re}\left\{\left[V_g/(Z_g+Z_g^*)\right] e^{i\omega t}\right\}$

s_o = available output signal power at the output terminals of the two-port (W)

n_o = available noise output power at the output terminals of the two-port (W).



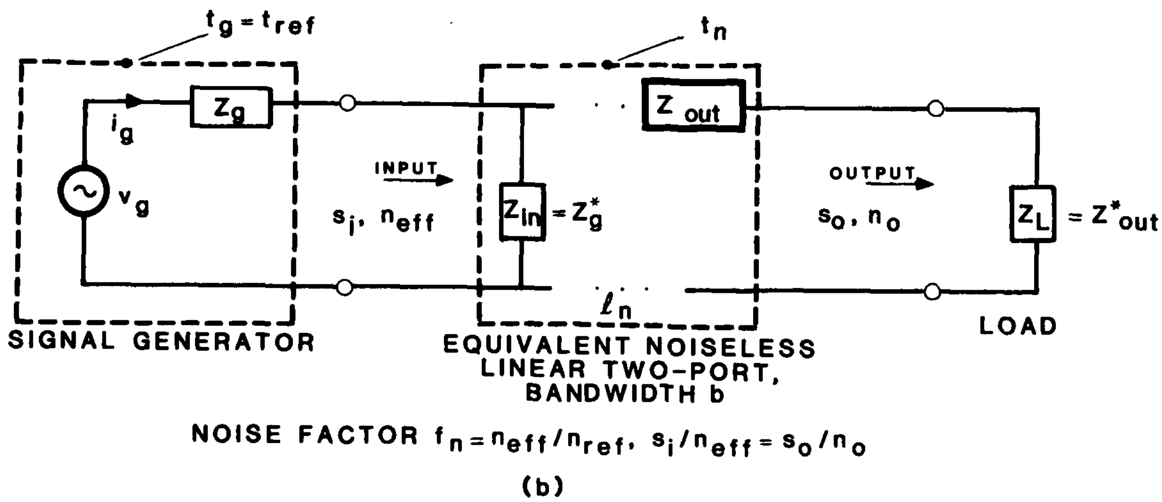


Figure I-1. Definition of Noise Factor of a Linear Two-Port Network
(a) Actual Two-Port with Internally-Generated Noise
(b) Equivalent Noiseless Two-Port

The available power from a source is defined to be the power delivered by the source to a load as though the load impedance were conjugate matched to the output impedance of the source. In computing available powers in figure I-1(a), the input impedance Z_{in} is set equal to Z_g^* (not Z_g made equal to Z_{in}^*) and the load impedance Z_L is set equal to Z_{out}^* (not Z_{out} made equal to Z_L^*). The noise factor f_n is therefore a function of Z_g^* and Z_{out}^* (not Z_{in} and Z_L).

For a source generator whose antenna external noise is zero and whose impedance is at an ambient temperature equal to the reference temperature, the available input noise power to the two-port of figure I-1(a) is equal to the reference noise power. Only for such conditions is the noise factor of a two-port equal to the ratio of the input to output signal-to-noise ratios of the network.

The available loss factor ℓ_n of a linear two-port is defined as[2]

$$\ell_n \equiv s_i/s_o \qquad \text{(I-2)}$$

where s_i and s_o are defined in Eq. (I-1).

From substitution of Eq. (I-2) into Eq. (I-1), the available noise output power n_o is given by

$$n_o = f_n \, n_{ref} / \ell_n \, , \quad t_g = t_{ref} \qquad \text{(I-3)}$$

With reference to figure I-1(b), the available output noise power referred to the input terminals of an equivalent noiseless two-port (denoted as the available effective noise power n_{eff}) is given by

$$n_{eff} \equiv n_o \, \ell_n = f_n \, n_{ref} \, , \quad t_g = t_{ref} \qquad \text{(I-4)}$$

From Eq. (I-4), the noise factor of a linear two-port is the available effective noise power normalized to the reference noise power.

The available effective noise power rise, Δn_{eff}, referred to the input terminals of an equivalent noiseless two-port, is defined as

$$\Delta n_{eff} \equiv n_{eff} - n_{ref} = kbt_{ref}\,(f_n - 1) \qquad \text{(I-5)}$$

The available effective noise power rise, Δn_{eff}, is the available noise power, referred to the input terminals, which is internally generated by the linear two-port. The available output noise power rise, Δn_o, at the output of the two-port, is defined as

$$\Delta n_o \equiv n_o - (n_{ref}/\ell_n) = kb\, t_{ref}\,(f_n - 1)/\ell_n \qquad \text{(I-6)}$$

The available output noise power rise, Δn_o, is the available noise power at the output of the network, which is internally generated by the linear two-port.

It is often convenient (but not necessary) to express a noise power ℓ_n in terms of its equivalent black body noise temperature $t = n/kb$. The noise temperatures corresponding to the various noise powers of Eq. (I-1) to Eq. (I-6) are defined below.

The reference noise temperature, t_{ref}, is defined as

$$t_{ref} \equiv n_{ref}/kb \qquad \text{[cf. Eq. (A-1)]} \qquad \text{(I-7)}$$

The effective noise temperature, t_{eff}, at the input of the equivalent noiseless two-port is defined as,

$$t_{eff} \equiv n_{eff}/kb = f_n\, t_{ref} \qquad \text{(I-8)}$$

The effective noise temperature rise, Δt_{eff}, at the input of the equivalent noiseless two-port is defined as

$$\Delta t_{eff} \equiv t_{eff} - t_{ref} = n_{eff}/kb = (f_n - 1)t_{ref} \tag{I-9}$$

The output noise temperature, t_o, at the output of the two-port is defined as

$$t_o \equiv n_o/kb = f_n\, t_{ref}/\ell_n \tag{I-10}$$

The output noise temperature rise, Δt_o, at the output of the two-port is defined as

$$\Delta t_o \equiv t_o - (t_{ref}/\ell_n) = n_o/kb = (f_n - 1)t_{ref}/\ell_n \tag{I-11}$$

In Eq. (I-1), the noise factor f_n is defined for a source impedance at an ambient temperature $t_g = t_{ref}$. Measurements of noise factor are often performed when the source impedance is at ambient temperature $t_g \neq t_{ref}$. For such a case, the measured noise factor is not equal to f_n. The measured noise factor, f_{n,t_g}, is defined as

$$f_{n,t_g} = (s_i/n_{ref})/(s_o/n_{o,t_g}) = \ell_n\, n_{o,t_g}/n_{ref}$$

$$= f_n\, n_{o,t_g}/n_o \tag{I-12}$$

where n_{o,t_g} is the available measured noise output power at the output of the two-port when the source impedance and is given by

$$n_{o,t_g} = n_o + \left(\frac{n_{ref}}{\ell_n}\right)\left(\frac{t_g}{t_{ref}}\right) = n_o + \left(\frac{n_{ref}}{\ell_n}\right)\left(\frac{t_g}{t_{ref}} - 1\right) \tag{I-13}$$

Substitution of Eq. (I-13) into Eq. (I-12) yields

$$f_{n,t_g} = (t_g/t_{ref}) + f_n - 1 \tag{I-14}$$

IB. Passive, Lumped, Series Impedance

With reference to figure I-2, consider a linear two-port network consisting of a lumped, passive, series impedance Z_n at an ambient temperature t_n, with an effective bandwidth b, a CW source generator with open-circuited signal voltage $v_g = \mathrm{Re}(V_g\, e^{j\omega t})$ and output impedance Z_g at ambient temperature $t_g = t_{ref}$, and a load impedance Z_L.

The available input signal power s_i, which is computed by conjugate matching the input impedance to Z_g, is given by (see Eq. I-1)

$$s_i = |V_g|^2/[8\mathrm{Re}(Z_g^*)] = |V_g|^2/[8\ \mathrm{Re}(Z_g)] \tag{I-15}$$

The available output signal power s_o, which is computed by conjugate matching the load to the output impedance $Z_n + Z_g$, is given by

$$s_o = |V_g|^2/[8\ \mathrm{Re}\ (Z_g + Z_n)^*] = |V_g|^2/[8\ \mathrm{Re}\ (Z_g + Z_n)] \tag{I-16}$$

From Eq. (I-2), the available loss factor ℓ_n is given by

$$\begin{aligned}\ell_n &= s_i/s_o = \mathrm{Re}(Z_g + Z_n)^*/\mathrm{Re}(Z_g^*)\\ &= 1 + [\mathrm{Re}(Z_n)/\mathrm{Re}(Z_g)]\end{aligned} \tag{I-17}$$

The open-circuited rms noise voltage, V_{noc}, at the output of the two-port is given by

$$V_{noc} = \{4\ kb\ [(\mathrm{Re}\ Z_g)t_{ref} + (\mathrm{Re}\ Z_n)\ t_n]\}^{1/2},\ t_g = t_{ref} \tag{I-18}$$

The available output noise power, n_o, is the noise power delivered to a load Z_L when Z_L is conjugate matched to the output impedance of the two-port. Accordingly,

IF. Cascaded Two-Port Network

Consider two cascaded linear two-port networks a and b with identical bandwidth B (see fig. I-4). Networks a and b, at ambient temperatures t_a and t_b, respectively, are characterized by noise factors f_a and f_b, and available loss factors ℓ_a and ℓ_b, respectively. The noise factors f_a, f_b, and available loss factors ℓ_a, ℓ_b are defined for the two-ports with their source impedances as connected in figure I-4 (not for each two-port connected separately to the generator and load). The generator output impedance Z_g is at an ambient temperature $t_g = t_{ref}$. The cascaded network noise factor, as a function of the individual network noise factors, is of particular interest. The derivation follows that of Friis[6].

The available output noise power n_{ab} at the output terminals of network b is by definition [see Eq. (I-3)] given by

$$n_{ab} = f_{ab}\, n_{ref}/\ell_{ab} \tag{I-55}$$

where

f_{ab} = noise factors of the two networks in cascade
ℓ_{ab} = available loss factor of the two networks in cascade = $\ell_a \ell_b$
n_{ref} = reference noise power = $kt_{ref}B$

The available output noise power n_a, at the output terminals of network a, is by definition [see Eq. (I-3)] given by

$$n_a = f_a\, n_{ref}/\ell_a \tag{I-56}$$

The available noise power $(n_a)_b$, at the output terminals of network b, due to the noise sources in network a and the Johnson noise of the generator impedance Z_g is given by

$$(n_a)_b = n_a k/\ell_b = f_a\, n_{ref}/\ell_a\, \ell_b \tag{I-57}$$

where

f_o = empirical minimum noise factor for any possible source impedance Z_g at an ambient temperature $t_g = t_{ref}$.

$y_{no}(g_{no},b_{no}) = g_{no} + j\, b_{no}$ = empirical complex noise parameter with the dimensions of admittance (mhos).

r_n = empirical noise parameters with the dimensions of resistance which accounts for the sensitivity of the noise factors to network source impedance (ohms).

The noise factor f_n given by Eq. (I-53) has a minimum value f_o for $y_{no} = 1/Z_g$.

For a passive linear two-port network, it follows by comparison of Eq. (I-24) with Eq. (I-53) that the empirical parameters reduce to

$$f_o = 1, \quad r_n = r_{n,eq}\,(t_n/t_{ref}), \quad y_{no} = 0; \text{ passive network} \qquad \text{(I-54)}$$

IE. Active Two-Port Network

Consider a linear two-port network whose general configuration is shown in figure I-1 but which is restricted to contain at least one active element. For an active network, the available output signal power can exceed the available input signal power and consequently the available loss factor ℓ_n can be less than unity. In active networks, it is often more convenient to express available output signal or noise powers in terms of the available gain factor g_n defined by

$$g_n \equiv s_o/s_i = 1/\ell_n \tag{I-52}$$

where s_o, s_i = available output and signal powers, respectively, of the linear two-port.

The equivalent lumped series resistance $r_{n,eq}$, which is defined in Eq. (I-23) for a passive network and which has the same available loss factors as the two-port network, can be negative in an active network since its available loss factor ℓ_n can be less than unity. The noise factor f_n, which is given by Eq. (I-24) for a passive network, is not applicable to an active network because the noise originating within an active network is not necessarily thermal noise generated by ohmic losses.

The noise factor f_n of any linear two-port network at an ambient temperature t_n for an arbitrary source impedance Z_g at an ambient temperature $t_g = t_{ref}$, may be characterized in terms of four empirical parameters of the network in a functional relationship given by [4],[5]

$$f_n = f_o + \frac{r_n}{Re(1/Z_g)} \left| (1/Z_g) - y_{no} \right|^2 \tag{I-53}$$

The transmission line noise factor, f_n, is found by substituting ℓ_n given by either Eq. (I-46) or Eq. (I-48) into Eq. (I-28). The equivalent, lumped series resistance $r_{n,eq}$ of the transmission line (as far as available loss factors or noise factors is concerned) is found by substituting either of the above expressions for ℓ_n into Eq. (I-23).

For the following special transmission line cases of interest, ℓ_n, f_n, and $r_{n,eq}$ reduce to

$$\ell_n = \begin{cases} 1, \ \gamma d = 0 & \text{(a)} \\ \infty, \ Z_g = 0 \text{ or } \Gamma = -1, \ \gamma d \neq 0 & \text{(b)} \\ \infty, \ Z_g = \infty \text{ or } \Gamma = 1, \ \gamma d \neq 0 & \text{(c)} \\ \exp(2\alpha d), \ Z_g/Z_o = 1 \text{ or } \Gamma = 0 & \text{(d)} \end{cases} \qquad \text{(I-49)}$$

$$f_n = \begin{cases} 1, \ \gamma d = 0 & \text{(a)} \\ \infty, \ Z_g = 0 \text{ or } \Gamma = -1, \ \gamma d \neq 0 & \text{(b)} \\ \infty, \ Z_g = \infty \text{ or } \Gamma = 1, \ \gamma d \neq 0 & \text{(c)} \\ 1 + [\exp(2\alpha d)-1](t_n/t_{ref}), \ Z_g/Z_o = 1 & \text{(d)} \end{cases} \qquad \text{(I-50)}$$

$$r_{n,eq} = \begin{cases} 0, \ \gamma d = 0 & \text{(a)} \\ \cosh^2(\gamma d)\ \mathrm{Re}[Z_o \tanh(\gamma d)], \ Z_g = 0 \text{ or } \Gamma = -1 & \text{(b)} \\ \infty, \ Z_g = 0 \text{ or } \Gamma = 1, \ \gamma d \neq 0 & \text{(c)} \\ [1 - \exp(2\alpha d)]\mathrm{Re}(Z_o), \ Z_g/Z_o = 1 & \text{(d)} \end{cases} \qquad \text{(I-51)}$$

Multiplying numerator and denominator by $[(Z_g/Z_o+1]$, dividing numerator and denominator by $[1+\exp(-2\gamma d)]$ and noting that $x' = -d$ corresponds to $x = 0$ and $x' = 0$ corresponds to $x = -d$, Eq. (I-44) reduces to

$$Z(x=0)\Big|_{Z(x=-d)=Z_g} = \frac{Z_g + Z_o \tanh(\gamma d)}{(Z_g/Z_o)\tanh(\gamma d)+1} \qquad \text{(I-45)}$$

Substituting Eq. (I-38) and Eq. (I-45) into Eq. (I-27), the available loss factor ℓ_n is given by

$$\ell_n = \frac{|[(Z_g/Z_o)\tanh(\gamma d)+1]\cosh(\gamma d)|^2}{\mathrm{Re}(Z_g)} \quad \mathrm{Re}\left[\frac{Z_g+Z_o\tanh(\gamma d)}{(Z_g/Z_o)\tanh(\gamma d)+1}\right] \qquad \text{(I-46)}$$

From Eq. (I-43),

$$Z_g = Z_o\,[1+\Gamma(x'=0)]/[1-\Gamma(x'=0)] \qquad \text{(I-47)}$$

Substitution of Eq. (I-47) into Eq. (I-46) yields after some algebraic manipulation an alternative expression for ℓ_n given by

$$\ell_n = \frac{\exp(2\alpha d)\{(1-|\Gamma|^2\exp(-4\alpha d) - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\,\mathrm{Im}[\Gamma\exp(-2\gamma d)]\}}{1-|\Gamma|^2 - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\,\mathrm{Im}\,\Gamma} \qquad \text{(I-48)}$$

where

$$\Gamma \equiv \Gamma(x'=0)\Big|_{Z(x'=0)=Z_g} = [(Z_g/Z_o)-1]/[(Z_g/Z_o)+1]$$

$$\gamma = \alpha + jB.$$

For the condition $Z(-d) = Z_g$ at $x = -d$, the forward travelling wave originates at $x = 0$ and propagates in the negative x direction whereas the reflected travelling wave originates at $x = -d$ and propagates in the positive x direction. It is therefore convenient to introduce a new coordinate axis $x' = -d-x$. The voltage $V(x')$, current $I(x')$, and impedance $Z(x')$ for the condition $Z(x'=0) = Z_g$ are given by [3]

$$V(x') = V_+ e^{-\gamma x'} + V_- e^{\gamma x'} = V_+ e^{-\gamma x'} \left[1 + \Gamma(x'=0)\, e^{2\gamma x'}\right] \tag{I-39}$$

$$I(x') = I_+ e^{-\gamma x'} + I_- e^{\gamma x'} = (V_+/Z_o)\, e^{-\gamma x'} \left[1 - \Gamma(x'=0)\, e^{2\gamma x'}\right] \tag{I-40}$$

$$Z(x') = V(x')/I(x') = Z_o \left[1 + \Gamma(x'=0)\, e^{2\gamma x'}\right] \Big/ \left[1 - \Gamma(x'=0)\, e^{2\ x'}\right]$$

$$= Z_o \left[1 + \Gamma(x')\right] \Big/ \left[1 - \Gamma(x')\right] \tag{I-41}$$

where

$\Gamma(x'=0) = V_-/V_+$ = voltage reflection coefficient at $x' = 0$

$\Gamma(x') = \Gamma(x'=0)\ {}^{2\gamma x'}$ = voltage reflection coefficient at position x'.

From Eq. (I-41),

$$Z(x'=0) = Z_g = Z_o\, [1 + \Gamma(x'=0)]/[1 - \Gamma(x'=0)] \tag{I-42}$$

From Eq. (I-42),

$$\Gamma(x'=0) = [(Z_g/Z_o) - 1]/[(Z_g/Z_o) + 1],\quad Z(x'=0) = Z_g \tag{I-43}$$

Substituting Eq. (I-43) into Eq. (I-41),

$$Z(x'= -d)\big|_{Z(x'=0)=Z_g} = \frac{Z_o\{1+\exp(-2\gamma d)[(Z_g/Z_o)-1]/[(Z_g/Z_o)+1]\}}{1-\exp(-2\gamma d)[(Z_g/Z_o)-1]/[(Z_g/Z_o)+1]} \tag{I-44}$$

From Eq. (I-31),

$$Z(0) = \infty = Z_o[1 + \Gamma(0)]/[1 - \Gamma(0)] \tag{I-32}$$

Consequently,

$$\Gamma(0) = 1, \ Z(0) = \infty \tag{I-33}$$

Substituting Eq. (I-33) into Eq. (I-29) and Eq. (I-31),

$$V(-d) = V_+ \, e^{\gamma d}\left[1 + \Gamma(0)\, e^{-2\gamma d}\right] = V_+ \, (e^{\gamma d} + e^{-\gamma d}), \ Z(0) = \infty \tag{I-34}$$

$$Z(-d) = Z_o\left[1 + \Gamma(0)\, e^{-2\gamma d}\right]\Big/\left[1 - \Gamma(0)\, e^{-2\gamma d}\right]$$

$$= Z_o \, (1 + e^{-2\gamma d})/(1 - e^{-2\gamma d}) = Z_o/\tanh(\gamma d), \ Z(0) = \infty \tag{I-35}$$

where $\tanh y = [1 - \exp(-2y)]/[1 + \exp(-2y)] = -\tanh(-y)$. The input impedance $Z(-d)$ is in series with the output impedance Z_g of the signal generator. The voltage $V(-d)$ is therefore given by

$$V(-d) = |V_g| \, Z(-d)/[Z_g + Z(-d)] = |V_g|/[(Z_g/Z_o) \tanh(\gamma d) + 1],$$

$$Z(0) = \infty \tag{I-36}$$

Substituting Eq. (I-36) into Eq. (I-34),

$$V_+ = \frac{|V_g|}{2 \cosh(\gamma d) \ [(Z_g/Z_o)\tanh(\gamma d)+1]}, \ Z(0) = \infty \tag{I-37}$$

Substituting Eq. (I-37) and Eq. (I-33) into Eq (I-29),

$$V(0)\big|_{Z(0)=\infty} = \frac{|V_g|}{[(Z_g/Z_o)\tanh(\gamma d)+1] \ \cosh(\gamma d)} \tag{I-38}$$

where $\cosh y = (e^y + e^{-y})/2$.

From Eq. (I-24), the transmission line noise factor, f_n, is given by

$$f_n = 1 + (\ell_n - 1) \frac{t_n}{t_{ref}} \tag{I-28}$$

where ℓ_n is given by Eq. (I-27).

The functional dependence of the parameters $V(0)|_{Z(0)=\infty}$ and $Z(0)|_{Z(-d)=Z_g}$ upon the characteristics of the signal generator and the transmission line are determined in the remainder of this section.

For the open circuit condition $Z(0) = \infty$ at $x = 0$, the standing wave voltage $V(x)$ at a position x $(-d \leq x \leq 0)$ along the transmission line may be considered as the sum of a foward travelling wave $V_+(x) = V_+ \exp(-\gamma x)$ originating at $x = -d$ and a reflected travelling wave $V_-(x) = V_- \exp(\gamma x)$ originating at $x = 0$. The complex voltage amplitude $V(x)$, complex current amplitude $I(x)$, and impedance $Z(x)$ are given by [(3)]

$$V(x) = V_+ e^{-\gamma x} + V_- e^{\gamma x} = V_+ e^{-\gamma x} \left[1 + \Gamma(0)\, e^{2\gamma x}\right] \tag{I-29}$$

$$I(x) = I_+ e^{-\gamma x} + I_- e^{\gamma x} = (V_+/Z_o) e^{-\gamma x}\left[1 - \Gamma(0) e^{2\gamma x}\right] \tag{I-30}$$

$$\begin{aligned} Z(x) = V(x)/I(x) &= Z_o \left[1 + \Gamma(0)\, e^{2\gamma x}\right] \Big/ \left[1 - \Gamma(0)\, e^{2\gamma x}\right] \\ &= Z_o\, [1 + \Gamma(x)]/[1 - \Gamma(x)] \end{aligned} \tag{I-31}$$

where

$\Gamma(0) = V_-/V_+$ = voltage reflection coefficient at $x = 0$

$\Gamma(x) = \Gamma(0) e^{2\gamma x}$ = voltage reflection coefficient at position x

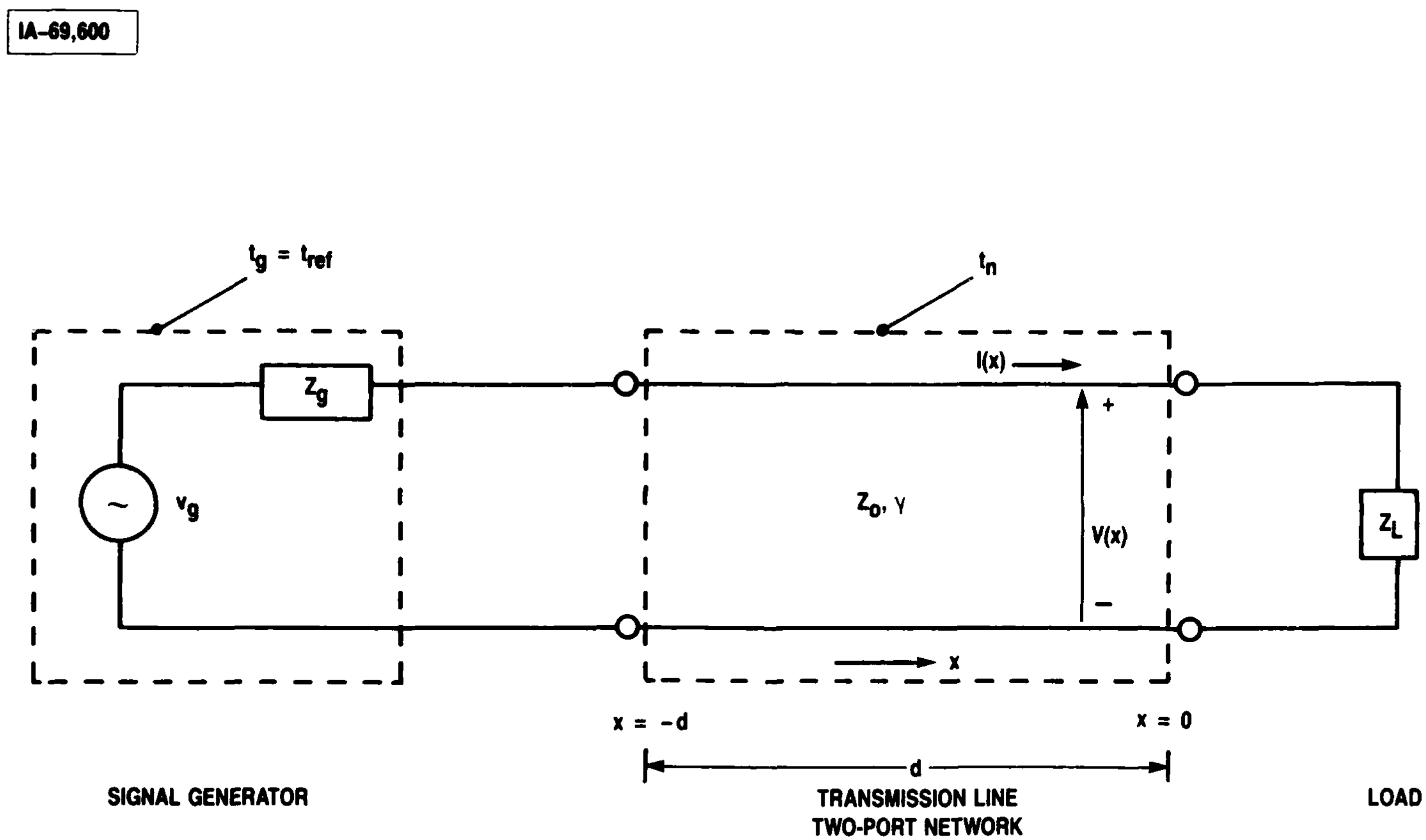


Figure I-3. Transmission Line Two-Port Network

ID. Passive Transmission Line

Consider a passive two-port network whose impedance elements are continuously distributed such as the transmission line of figure I-3. The transmission line is at an ambient temperature t_n and is fed by a signal generator of open-circuited voltage $v_g(t) = \mathrm{Re}(V_g\, e^{j\omega t})$ and output impedance Z_g at an ambient temperature $t_g = t_{ref}$. The transmission line is of length d with a characteristic impedance Z_o and a propagation constant $\gamma = \alpha + j\beta$. The transmission line impedance, $Z(x) = V(x)/I(x)$, is a function of the voltage $V(x)$ and current $I(x)$ which vary with position x along the transmission line.

The available CW input signal power, s_i, at the input terminals $x = -d$ of the transmission line is given by

$$s_i = |V_g|^2/(8 \text{ Re } Z_g) \tag{I-25}$$

The available CW output signal power at the output terminals $x = 0$ of the transmission line is given by

$$s_o = \left| V(0)\big|_{Z(0)=\infty} \right|^2 \Big/ \left[8 \text{ Re } Z(0)\big|_{Z(-d)=Z_g} \right] \tag{I-26}$$

where

$V(0)\big|_{Z(0)=\infty}$ = open-circuited complex voltage amplitude at $x = 0$

$Z(0)\big|_{Z(-d)=Z_g}$ = output impedance, of the transmission line at $x = 0$ looking back in the direction of the signal generator for the condition $Z(-d) = Z_g$ at $x = -d$.

The transmission line available loss factor, ℓ_n, is given by Eq. (I-2) as

$$\ell_n = \frac{s_i}{s_o} = \frac{|V_g|^2 \text{ Re } \left[Z(0)\big|_{Z(-d) = Z_g} \right]}{\left| V(0)\big|_{Z(0) = \infty} \right|^2 \text{ Re}(Z_g)} \tag{I-27}$$

At an ambient temperature t_n, the resistance $r_{n,eq}$ has a noise factor given by Eq. (I-21). The noise factor f_n of a passive linear two-port network may therefore be expressed as

$$f_n = 1 + (r_{n,eq}/\mathrm{Re}\, Z_g)(t_n/t_{ref}) = 1 + (\ell_n - 1)(t_n/t_{ref}), \quad t_g = t_{ref} \qquad \text{(I-24)}$$

IC. Passive Two-Port Network

Consider a linear two-port network whose general configuration is shown in figure I-1 but which is restricted to contain only passive elements. The passive network may be any configuration of lumped impedance elements (such as resistances, capacitances, and inductances) or distributed impedance elements (such as a transmission line). The two-port is at an ambient temperature t_n and is characterized by an available loss factor ℓ_n for a source output impedance Z_g at an ambient temperature $t_g = t_{ref}$ where t_{ref} is the reference temperature.

The available loss factor ℓ_n is the ratio of the available input to output signal powers (see Eq. I-2). For a passive network, the available loss factor $\ell_n \geq 1$ since the available output signal power can never exceed the available input signal power. The available loss factor ℓ_n of a passive network is given by

$$\ell_n = 1/\xi \quad , \quad \text{passive network} \qquad \text{(I-22)}$$

where

$\xi = s_o/s_i$ = <u>available signal power efficiency</u> of a passive network

s_o, s_i = available output and input signal powers, respectively, which are functions of the output impedances looking back toward the source at the output and input terminals, respectively

Consider a passive two-port network whose available loss factor ℓ_n and source impedance Z_g are known. The two-port network and source impedance are at ambient temperatures t_n and $t_g = t_{ref}$, respectively. From Eq. (I-14), it is always possible to replace the passive two-port network by an <u>equivalent</u>, <u>lumped</u>, <u>series resistance</u> $r_{n,eq}$ which has the same available loss factor ℓ_n as the two-port network provided that

$$r_{n,eq} = (\ell_n - 1) \text{ Re } Z_g \qquad \text{(I-23)}$$

$$n_o = \frac{V^2_{noc}}{ReZ_L}\left[\frac{ReZ_L}{Re\ (Z_g + Z_n) + Re\ Z_L}\right]^2 \Bigg|\ Z_L = Re(Z_g + Z_n)^*$$

$$= \frac{V^2_{noc}}{4\ Re(Z_g + Z_n)} = \frac{kb\ [(ReZ_g)t_{ref} + (ReZ_n)t_n]}{Re(Z_g + Z_n)}\ ,\ t_g = t_{ref} \tag{I-19}$$

Subtitution of Eq. (I-15), Eq. (I-16), and Eq. (I-19) into Eq. (I-1) yields a noise factor f_n given by

$$f_n = 1 + \frac{(Re\ Z_n)t_n}{(Re\ Z_g)t_{ref}}\ ,\ t_g = t_{ref} \tag{I-20}$$

However, it is noted from Eq. (I-17) that Re Z_n/Re $Z_g = \ell_n - 1$. Accordingly, Eq. (I-20) reduces to

$$f_n = 1 + (\ell_n - 1)(t_n/t_{ref})\ ,\ t_g = t_{ref} \tag{I-21}$$

The noise factor f_n given by Eq. (I-20) is valid only for a passive, lumped, series impedance whose available loss factor ℓ_n is given by Eq. (I-17). However, it will be shown in the following section that the noise factor f_n given by Eq. (I-21) is valid for any passive two-port network of known available loss factor $\ell_n \geq 1$.

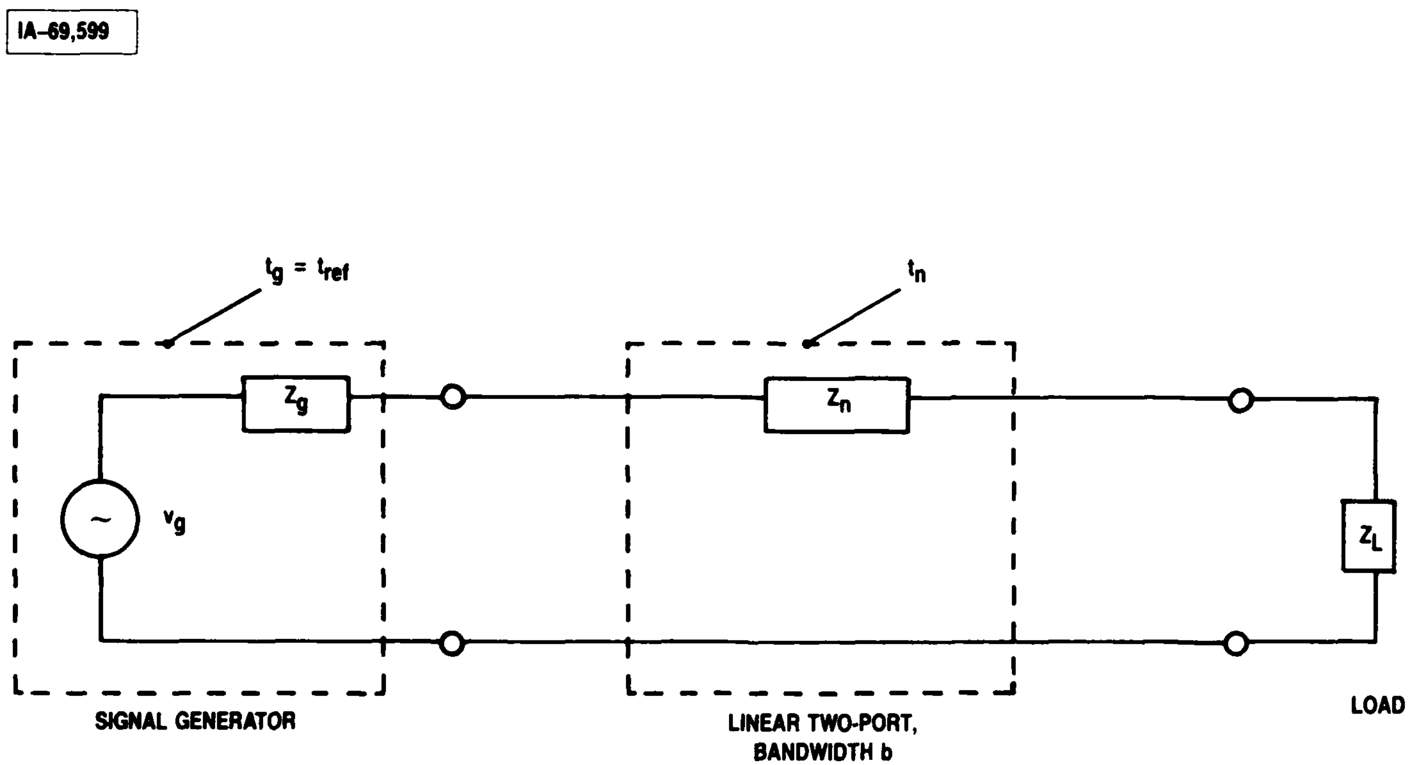


Figure I-2. Two-Port Network Consisting of Lumped, Passive, Series Impedance

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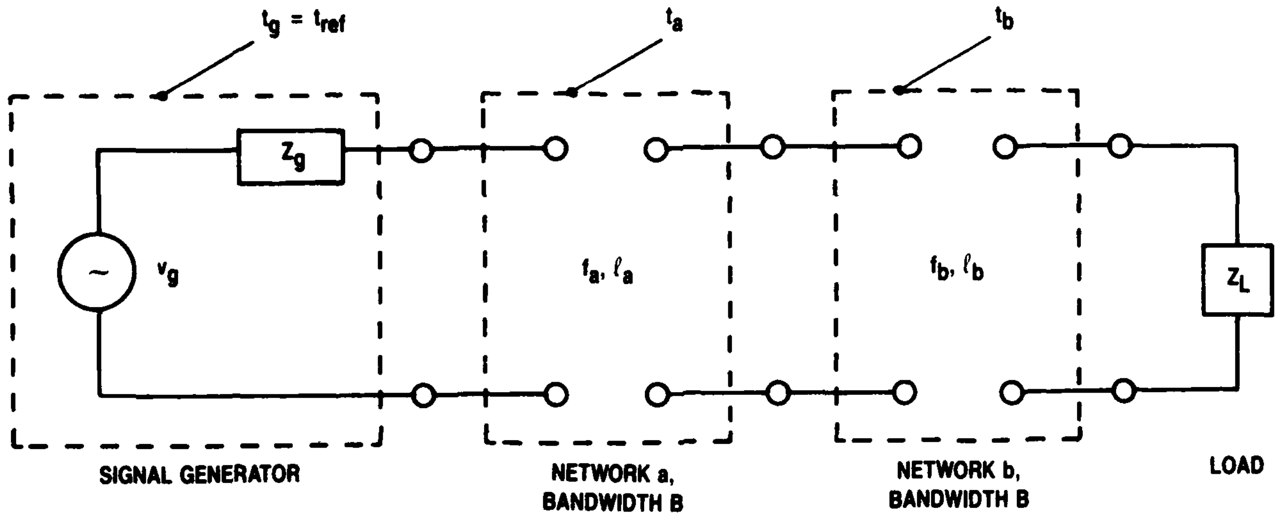

Figure I-4. Two Linear Two-Port Networks in Cascade

The available output noise power rise Δn_b, at the output terminals of network b, which is internally generated by network b is by definition [see Eq. (I-6)] given by

$$n_b = n_{ref} (f_b - 1) / \ell_b \tag{I-58}$$

The available output noise power n_{ab}, given by Eq. (I-55), is also given by

$$n_{ab} = (n_a)_b + n_b \tag{I-59}$$

Substituting Eqs. (I-55), (I-57), and (I-58) into Eq. (I-59),

$$f_{ab} = f_a + (f_b - 1)\ell_a \tag{I-60}$$

IG. Lossless Antenna with External Noise

Consider a loss-less receiving antenna with an output impedance Z_g at an ambient temperature $t_g = t_{ref}$ and with open-circuited rms signal and noise voltages, v_g and v_a, respectively, as shown in figure I-5. The output impedance $Z_g = r_a + jx_a$ where r_a and x_a are the antenna radiation resistance and reactance, respectively. The voltage $v_g = [2\ s(d)\ \eta_o]^{1/2}$ where s(d) is the available signal power at the output terminals of the loss-less antenna (see figure 1 of section 2) and η_o is the free-space wave impedance ≈122 ohms. The voltage $v_a = [2n_a\eta_o]^{1/2}$ where n_a is the antenna external available noise power at the output terminals of the loss-less antenna with an effective bandwidth b.

The antenna external noise may be treated as a fictional two-port network characterized by an available loss factor ℓ_a and an antenna external noise factor f_a as shown in figure I-4. The available output and input signals powers, of the fictional two-port network, are equal. Accordingly, from Eq. (I-2),

$$\ell_a = 1 \tag{I-61}$$

The available output noise power $n_o = n_a$. The reference noise power $n_{ref} = kt_{ref}\ b$. Therefore, from Eq. (I-3), the antenna external noise factor f_a is given by

$$f_a = n_a/n_{ref} \tag{I-62}$$

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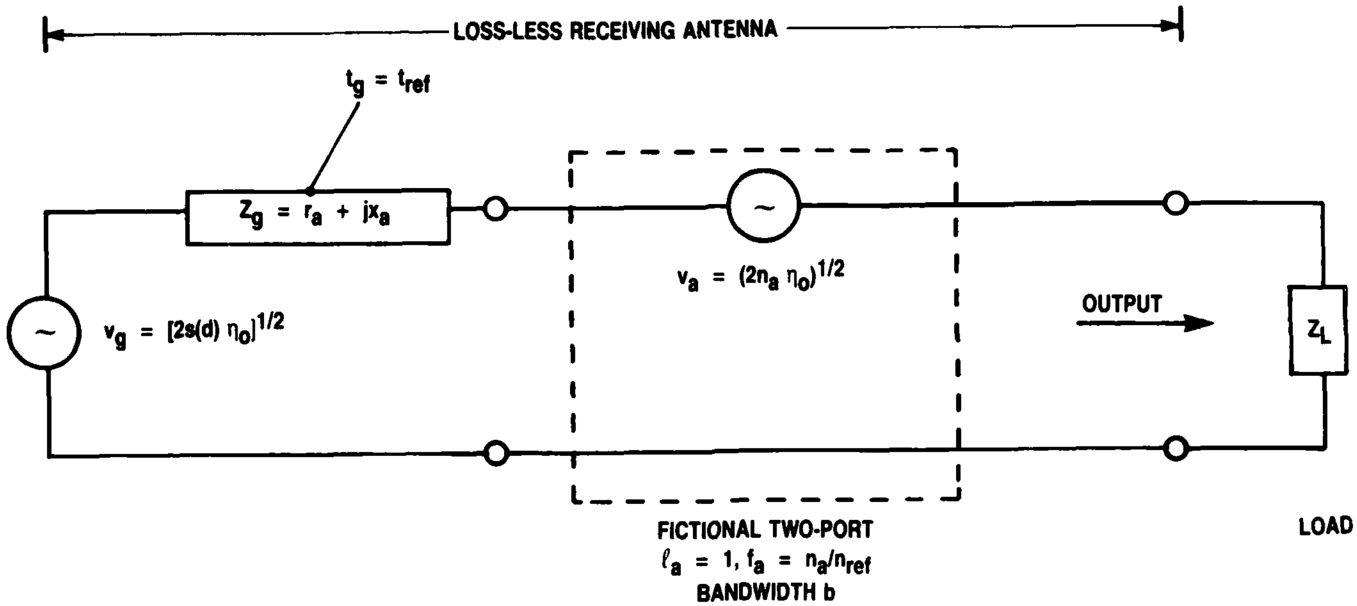

Figure I-5. Lossless Receiving Antenna with External Noise

IH. Radio Receiving System

The noise equivalent circuit of a radio receiving system (see figure I-6) may be considered as five cascaded linear two-port networks, each with an effective bandwidth b, in series with a source impedance Z_g equal to the output impedance of the equivalent lossless receiving antenna. Figure I-6 is the noise equivalent circuit of the radio receiving system in figures 1 and 2 of section 2. In figure I-6, the subscript r to denote "receiving system" has been omitted and the reactance and ideal transformer elements of network 3 are not explicitly shown although they are implicitly included in the noise parameters of networks 4 and 5 which follow these elements.

The source impedance Z_g is given by $Z_g = r_a + jx_a$ where r_a and x_a are the radiation resistance and reactance, respectively, of the receiving antenna. Network 1 accounts for the antenna external noise which is characterized by an antenna external noise factor f_a and an available loss factor $\ell_a = 1$ [see Eq. (I-61) and (I-62)]. Network 2 accounts for the ohmic loss resistance r_c of the antenna circuit at ambient temperature t_c with a noise factor f_c and available loss factor ℓ_c. Network 3 accounts for the ohmic loss resistance $(r_m + r_s)$, at ambient temperature t_m, of the reactive element and switch of the matching network which is characterized by a noise factor f_m and available loss factor ℓ_m. Network 4 accounts for the equivalent loss resistance $r_{n,eq}$ at ambient temperature t_n, of the transmission line which is characterized by a noise factor f_n and available loss factor ℓ_n. Network 5 accounts for the receiver noise which is characterized by a noise factor f_r and available gain factor g_r.

Networks 1 and 2 in cascade have a noise factor f_{12} given by Eq. (I-60) and Eq. (I-21) as

$$f_{12} = f_a + (f_c - 1)\ell_a = f_a + (\ell_c - 1)(t_c/t_{ref}) \tag{I-63}$$

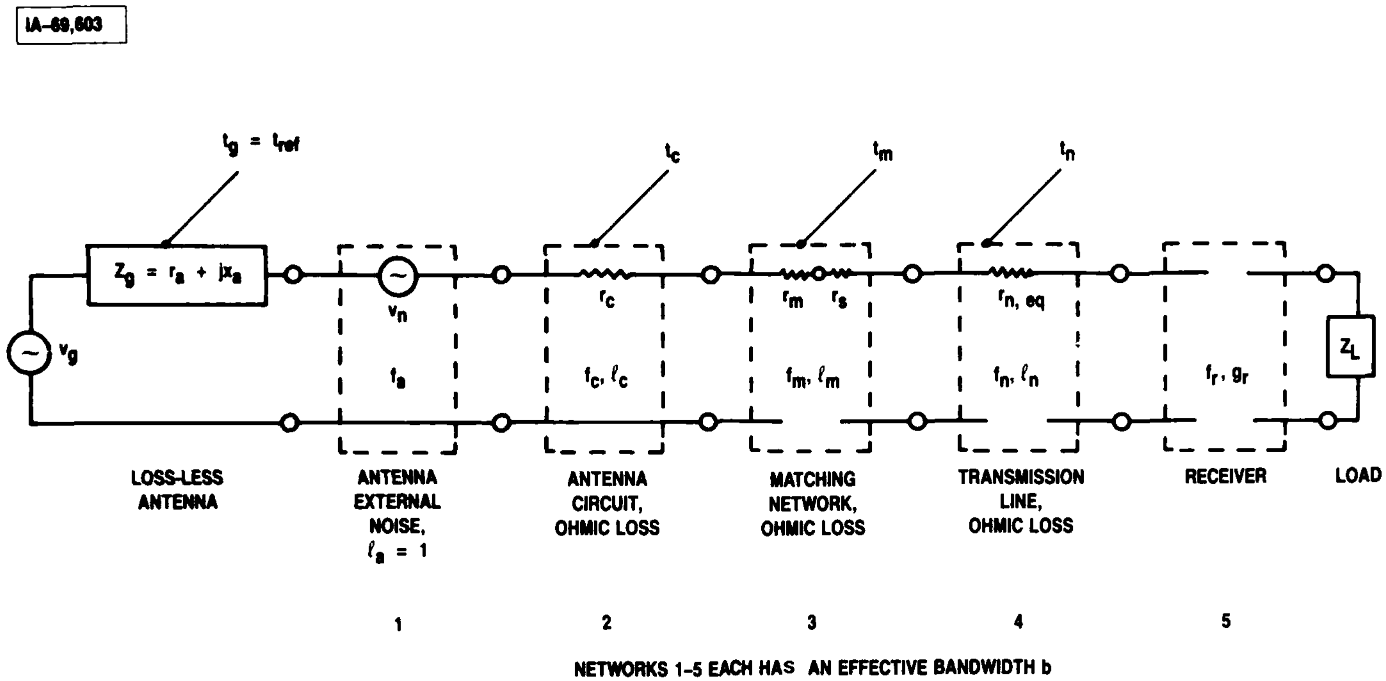

Figure I-6. Noise Equivalent Circuit of Radio Receiving System

Networks 1, 2, and 3 in cascade have a noise factor f_{123} given by Eqs. (I-60), (I-21), and (I-63) as

$$f_{123} = f_{12} + (f_m - 1)\ell_{12} = [f_a + (\ell_c - 1)(t_c/t_{ref})] + \ell_c(\ell_n - 1)(t_m/t_{ref}) \tag{I-64}$$

where $\ell_{12} = \ell_a \ell_c = \ell_c$

Networks 1, 2, 3, and 4 in cascade have a noise factor f_{1234} given by Eqs. (I-60), (I-24), and (I-6) as

$$\begin{aligned} f_{1234} &= f_{123} + (f_m - 1)\ell_{123} = [f_a + (\ell_c - 1)(t_c/t_{ref}) + \ell_c(\ell_m/t_{ref})] \\ &= \ell_c \ell_m(\ell_n - 1)(t_n/t_{ref}) \end{aligned} \tag{I-65}$$

where $\ell_{123} = \ell_a \ell_c \ell_m = \ell_c \ell_m.$

Networks 1, 2, 3, 4, and 5 in cascade have a noise factor f_{12345} which is designated as the <u>system operating noise factor</u>, f, and which is given by Eqs. (I-60) and (I-65) as

$$\begin{aligned} f_{12345} \equiv f = f_{1234} + (f_r - 1)\,\ell_{1234} &= [f_a + (\ell_c - 1)(t_c/t_{ref}) \\ &+ \ell_c(\ell_m - 1)(t_m/t_{ref}) + \ell_c \ell_m (\ell_n - 1)(t_n/t_{ref})] \\ &+ \ell_c \ell_m \ell_n (f_r - 1) \end{aligned} \tag{I-66}$$

where $\ell_{1234} = \ell_a \ell_c \ell_m \ell_n = \ell_c \ell_m \ell_n.$

For the network ambient temperatures equal to the reference temperature t_{ref}, Eq. (I-66) reduces to

$$f = f_a - 1 + \ell_c \ell_m \ell_n f_r, \qquad t_c = t_m = t_n = t_{ref} \tag{I-67}$$

The system (effective) available noise power, n, referred to the input terminals of an equivalent noiseless receiving system is given by

$$n = f\, n_{ref} \tag{I-68}$$

where $n_{ref} = k\, t_{ref} b$. Since network 1 has an available loss factor $f_a = 1$, the system available noise power, n, may also be referred to the output terminals of network 1 which is identical to the output terminals of the equivalent lossless antenna with antenna external noise.

The system available output noise power, n_o, at the output terminals of the receiver (network 5), is given by

$$n_o = n/\ell_{12345} = f\, n_{ref}/(\ell_c\, \ell_m\, \ell_n/g_r) \tag{I-69}$$

where $\ell_{12345} = \ell_a\, \ell_c\, \ell_m\, \ell_n/g_r = \ell_c\, \ell_m\, \ell_n/g_r$.

Eqs. (I-66) - (I-69) are a function of the available loss factors ℓ_c, ℓ_m, and ℓ_n. With reference to figure (I-5) (or the impedance equivalent circuit of figure 2 of section 2), the real part of the source impedance to networks 2 and 3 is r_a and $(r_a + r_c)$, respectively. With reference to Eq. (I-17), the available loss factors ℓ_c and ℓ_m are given by

$$\ell_c = 1 + (r_c/r_a) \tag{I-70}$$

$$\ell_m = 1 + [(r_m + r_s)/(r_c + r_a)] \tag{I-71}$$

With reference to Eq. (I-48) and figure 2 of section 2, the transmission line available loss factor, ℓ_n, is given by

$$\ell_n = \frac{\exp(2\alpha d)\,\{1 - |\Gamma|^2 \exp(-4\alpha d) - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\,\mathrm{Im}\,[\Gamma \exp(-2\gamma d)]\}}{1 - |\Gamma|^2 - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\,\mathrm{Im}\,\Gamma} \tag{I-72}$$

where

d = length of transmission line (m)

$\gamma = \alpha + j\beta$ = propagation constant of transmission line (nepers/m)

Γ = voltage reflection coefficient = $(Z - Z_o)/Z + Z_o)$

Z_o = characteristic impedance of transmission line (ohms)

Z = source impedance to the transmission line (ohms)

$= a^2[r_a + r_c = r_m + r_s) + j(x_a + x_m)]$

$= \begin{cases} Z_o, & \text{antenna impedance conjugate matched to transmission line} \\ r_a + jx_a + r_c, & \text{no matching network} \end{cases}$

a = transformer turns ratio of matching network

x_m = reactance of matching network (ohms)

References (Appendix I)

1. C.C.I.R., "Operating Noise Threshold of a Radio Receiving System", 11th Plenary Assembly, Oslo, Norway (1966), Report 413, Annex 1, Int. Radio Consultative Committee, Int. Telecommun. Union, Geneva, Switzerland, 1967. The noise factor f_n of a linear two-port may also be alternatively defined by $f_n \equiv n_{eff}/n_{ref}$ where n_{eff} is the available output noise power referred to the input terminals of the equivalent noiseless two-port (see Eq. I-4). Eq. (I-1) then follows by requiring $s_i/n_{eff} = s_o/n_o$.

2. In Ref. [1], the available loss and gain factors are denoted by ℓ'_n and g'_m, respectively, where the prime denotes available power. In the present paper the prime is dropped for the purpose of simplifying the notation.

3. R. B. Adler, L. J. Chu, and R. M. Fano, "Electromagnetic Energy and Transmission" (John Wiley and Sons, Inc., NY, 1960), pp 70-105.

4. H. A. Haus, et al, "IRE Standards on Methods of Measuring Noise in Linear Two-Ports, 1959, Proc. of the IEEE, Vol. 48, pp. 61-68, January 1960.

5. H. A. Haus, et al, "Representation of Noise in Linear Two-Ports", Proc. of the IRE, Vol. 48, pp. 69-74, January 1960.

6. H. T. Friis, "Noise Figures of Radio Receivers, Proc. IRE, Vol. 32, No. 7 pp. 419-422, July 1944. Please note the typographical error in Eq. (15) of Ref [6].

APPENDIX II

COMPUTER PROGRAM SONF (SYSTEM OPERATING NOISE FIGURE)

CONTENTS

II A. Description

Program SONF (System Operating Noise Figure) computes the expected value and variance of the receiving system operating noise figure relative to thermal noise at temperature 288 deg K and referenced to the output terminals of an equivalent receiving antenna with zero ohmic loss. The program is specifically written for the frequency band 20-102 MHz.

Particular features of the program are the inclusion of external man-made environmental noise and the effect of antenna impedance mismatch on receiver and transmission line loss factors.

The program is written in ANSI Fortran and is compatible with the Digital Equipment Corporation PDP-11/70 RSX-11M-Plus computer operating system.

The input variables, constants, derived output variables and numerical values of the input variables of the program SONF are listed in Tables 1, 2, 3, and 4, respectively.

TABLE II-1

INPUT VARIABLES, SYSTEM OPERATING NOISE FIGURE

	NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION	UNITS
frequency	1	f_{MHz}	FMHZ	rf carrier frequency	Hz
	2	b	B	receiver noise power effective bandwidth	Hz
temperature	3	t_c	TC	ambient temperature of the receiving antenna circuit	deg K
	4	t_m	TM	ambient temperature of the receiving matching network	deg K
	5	t_n	TN	ambient temperature of the receiving transmission line	deg K
antenna	6	$r_{c,r}$	RCR	ohmic loss resistance of receiving antenna circuit	ohms
	7	$r_{a,}$	RAR	radiation resistance of receiving antenna	ohms
	8	$x_{a,r}$	XAR	input reactance of receiving antenna	ohms
matching network	9	$r_{m,r}$	RMR	ohmic loss resistance of receiving antenna matching network (excluding switch)	ohms
	10	$x_{m,r}$	XMR	reactance of receiving antenna matching network	ohms
	11	a	A	ratio of secondary to primary turns of ideal transformer of receiving antenna matching network	———
	12	$r_{s,r}$	RSR	ohmic loss resistance of switch of receiver antenna matching network	ohms

TABLE II-1

INPUT VARIABLES, SYSTEM OPERATING NOISE FIGURE (cont.)

	NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION	UNITS
receiver noise	13	f_o	FO	minimum noise factor of receiver for any possible source admittance y_s	——
	14	r_n	RN	receiver noise empirical parameter with the dimensions of resistance	ohms
	15	g_{no}	GNO	receiver noise empirical parameter with the dimensions of conductance	mhos
	16	b_{no}	BNO	receiver noise empirical parameter with the dimensions of susceptance	mhos
transmission line	17	$Re(z_{or})$	REZOR	real part of the characteristics impedance of the receiving transmission line	ohms
	18	$Im(z_{or})$	IMZOR	imaginary part of the characteristics impedance of the receiving transmission line	ohms
	19	α_r	ALPHAR	attenuation constant of the receiving transmission line	nepers/m
	20	β_r	BETAR	phase constant of the receiving transmission line	nepers/m
	21	d_r	[illegible]	length of receiving transmission line	m
environmental noise	22	$\langle F_a \rangle$	FAMEAN	expected value of external noise figure of receiving antenna	dB
	23	$D_{u,F_{a,t}}$	DUFAT	$F_{a,t}(90\%) - F_{a,t}(50\%)$ = upper decile minus the median, of time variability, of external noise figure of receiving antenna	dB
	24	$D_{\ell,F_{a,t}}$	DLFAT	$F_{a,t}(50\%) - F_{a,t}(10\%)$ = median minus the lower decile, of time variability, of external noise figure of receiving antenna	dB
	25	$\sigma_{F_{a,\ell}}$	FALSTD	standard deviation of location variability of external noise figure of receiving antenna	dB

```
      FATSTD=(1./1.28)*(.5*(DUFAT**2.+DLFAT**2.)-.1592*
     4 (DUFAT-DLFAT)**2.)**.5
      FASTD=(((FALSTD)**2.+(FATSTD**2.))**.5)
      SFAMEN=10.**((FAMEAN/10.)+.5*ALOG(10.)*(FASTD/10.)**2.)
      SFASTD=SFAMEN*(10.**(((FASTD/10.))**2.*ALOG(10.))-1.)**.5
      LMR=(RAR+RCR+RMR+RSR)/(RAR+RCR)
      LCR=(RAR+RCR)/RAR
      SFMEAN=SFAMEN+(LCR-1)*(TC/TO)+LCR*(LMR-1)*(TM/TO)+LCR*LMR*(LNR-1)*
     N (TN/TO)+LCR*LMR*LNR*(FR-1)
      SFSTD=SFASTD
      FSTD=10*(((1/ALOG(10.))*ALOG 10(1.0+((SFSTD**2.)/(SFMEAN**2.))))**.5)
      FMEAN=10*(ALOG 10(SFMEAN)-.5*(FSTD/10)**2*ALOG(10.))
      NSTD=FSTD
C
C     *******************CALCULATE W**************************
      B=1.7E+4
      W=30+10*ALOG 10(K*TO*B)
C
C     *******************CALCULATE NMEAN N=W+<F>*************
      AN=FMEAN+W
      DFMEAN=(FMEAN-FAMEAN)
      SDFMEN=(SFMEAN/SFAMEN)
      WRITE(1,873)
C
C     ******************OUTPUT CALCULATED VARIABLES***********
C
  873 FORMAT(23X,'DERIVED  VARIABLES,TABLE 3'/)
      WRITE(1,874)W,ZOUT
  874 FORMAT(1X,'1  W= ',E10.4,' (dBm)',16X,
     1 '2  ZOUT= (',E10.4,' ,  ',E10.4,') (OHMS)'/)
      WRITE(1,875)ZOR
  875 FORMAT(1X,'3  ZOR= (',E10.4,' ,  ',E10.4,') (OHMS)'/)
      WRITE(1,876)REFLR
  876 FORMAT(1X,'4  REFLR= (',E10.4,' ,  ',E10.4,') (-----)'/)
      WRITE(1,877)GAMMAR
  877 FORMAT(1X,'5  GAMMAR= (',E10.4,' ,  ',E10.4,') (NEPERS/METER)'/)
      WRITE(1,878)YS
  878 FORMAT(1X,'6  YS= (',E10.4,' ,  ',E10.4,') (MHOS)'/)
      WRITE(1,879)YNO,FR
  879 FORMAT(1X,'7  YNO= (',E10.4,' ,  ',E10.4,') (MHOS)',2X,
     4 '8  FR= ',E10.4,' (-----)'/)
      WRITE(1,880)FATSTD,FASTD
  880 FORMAT(1X,'9  FATSTD= ',E10.4,' (dB)',12X,
     4 '10 FASTD= ',E10.4,' (dB)'/)
      WRITE(1,881)SFAMEN,SFASTD
  881 FORMAT(1X,'11 SFAMEAN= ',E10.4,' (-----)',8X,
     4 '12 SFASTD= ',E10.4,' (-----)'/)
      WRITE(1,950)
  950 FORMAT('1','PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE  1/13/84
     4 ',1X,'PAGE 2')
      WRITE(1,910)B3
  910 FORMAT(1X,'SCENARIO: ',1X,A65,1X)
      WRITE(1,920)C3
      WRITE(1,920)D3
      WRITE(1,920)E3
      WRITE(1,920)F3
      WRITE(1,930)G3
  920 FORMAT(11X,A40)
  930 FORMAT(11X,A40/)
      WRITE(1,882)LCR,LMR
  882 FORMAT(1X,'13 LCR= ',E10.4,' (-----)',12X,'14 LMR= ',E10.4,
```

```
C
      READ(3,820)I,J
  820 FORMAT(2I2)
      IF ((I.EQ.1) .AND. (J.EQ.1)) THEN
         FAMEAN=(76.8-27.7*ALOG 10(FMHZ))
         DUFAT=(10.5+0.093*(FMHZ-20.0))
         DLFAT=(7.6+0.0179*(FMHZ-20.0))
         FALSTD=(4.93+0.079*(FMHZ-20.0))
      ELSEIF ((I.EQ.2) .AND. (J.EQ.1)) THEN
         FAMEAN=(72.5-27.7*ALOG 10(FMHZ))
         DUFAT=(10.6+0.061*(FMHZ-20.0))
         DLFAT=(6.5+0.021*(FMHZ-20.0))
         FALSTD=(4.65-0.024*(FMHZ-20.0))
      ELSEIF ((I.EQ.3) .AND. (J.EQ.1)) THEN
         FAMEAN=(67.2-27.7*ALOG 10(FMHZ))
         DUFAT=(7.8-0.089*(FMHZ-20.0))
         DLFAT=(5.5-0.132*(FMHZ-20.0))
         FALSTD=(4.53-0.046*(FMHZ-20.0))
      ELSEIF ((I.EQ.1) .AND. (J.EQ.2)) THEN
         FAMEAN=(76.8-27.7*ALOG 10(FMHZ))
         DUFAT=(13.1-0.022*(FMHZ-48.0))
         DLFAT=(8.1-0.44*(FMHZ-48.0))
         FALSTD=(7.13+0.030*(FMHZ-48.0))
      ELSEIF ((I.EQ.2) .AND. (J.EQ.2)) THEN
         FAMEAN=(72.5-27.7*ALOG 10(FMHZ))
         DUFAT=(12.3+0.0037*(FMHZ-48.0))
         DLFAT=(7.1-0.042*(FMHZ-48.0))
         FALSTD=(3.98-0.023*(FMHZ-48.0))
      ELSE
         FAMEAN=(67.2-27.7*ALOG 10(FMHZ))
         DUFAT=(5.3+0.096*(FMHZ-48.0))
         DLFAT=(1.8+0.024*(FMHZ-48.0))
         FALSTD=(3.23-0.0109*(FMHZ-48.0))
      ENDIF
      WRITE(1,838)
  838 FORMAT(1X,'ENVIRONMENTAL NOISE')
      WRITE(1,840)FAMEAN,DUFAT
  840 FORMAT(1X,'22 FAMEAN= ',E10.4,' (dB)',14X,
     6 '23 DUFAT= ',E10.4,' (dB)')
      WRITE(1,850)DLFAT,FALSTD
  850 FORMAT(1X,'24 DLFAT= ',E10.4,' (dB)',15X,
     6 '25 FALSTD= ',E10.4,' (dB)'//)
C
      WRITE(1,851)
  851 FORMAT(26X,'CONSTANTS,TABLE 2'/)
      WRITE(1,852)TO,K
  852 FORMAT(1X,'1  TO= ',E10.4,' (DEG K)',15X,
     6 '2  K= ',E10.4,' (J/DEG K)'//)
      GAMMAR=CMPLX(ALPHAR,BETAR)
      ZOUT=CMPLX(((A**2.)*(RAR+RCR+RMR+RSR)),((A**2.)*(XAR+XMR)))
      YNO=CMPLX(GNO,BNO)
      REFLR=(ZOUT-ZOR)/(ZOUT+ZOR)
      YS=(1./ZOR)*(1.-(REFLR*CEXP(-2.*GAMMAR*DR)))/(1.+REFLR*
     C (CEXP(-2.*GAMMAR*DR)))
      RYS=REAL(YS)
      FR=FO+RN/(RYS)*(CABS(YS-YNO))**2.
      RREFLR=AIMAG(REFLR)
      RERFLR=AIMAG(REFLR*EXP(-2.*BETAR*DR))
      LNR=(EXP(2.*ALPHAR*DR)*(1.-((CABS(REFLR))**2.)*EXP(-4.*ALPHAR*DR))+
     2 ((-2.)*(IMZOR/REZOR))*AIMAG(REFLR*CEXP(-2.*GAMMAR*DR)))/
     3 (1.-((CABS(REFLR))**2.)+((-2.)*(IMZOR/REZOR))*(RREFLR))
```

```
C
      RCR=1.939E-4*((FMHZ)**.5)
      RAR=(2.84E-4)*((FMHZ)**2.)
      XAR=(-3.0E+4)/FMHZ
      WRITE(1,505)RCR,RAR
  505 FORMAT(1X,'6  RCR= ',E10.4,' (OHMS)',16X,
     6 '7  RAR= ',E10.4,' (OHMS)')
      WRITE(1,510)XAR
  510 FORMAT(1X,'8  XAR= ',E10.4,' (OHMS)'/)
      WRITE(1,515)
  515 FORMAT(1X,'MATCHING NETWORK')
C
C
      IMZOR=(1.25E-2)-2.65*((1/FMHZ)**.5)
      ZOR=CMPLX(REZOR,IMZOR)
      ALPHAR=1.68E-3*(FMHZ**.5)+8.0E-6*(FMHZ)
      BETAR=(3.18E-2)*FMHZ
C
C     **INPUT (1) FOR MATCHED NETWORK, INPUT (0) FOR NO MATCHING NETWORK**
C
  710 FORMAT(I)
      READ(3,710)N
      IF (N .LT. 1) THEN
         RMR=0.0
         XMR=0.0
         RSR=0.0
         A=1.0
      ELSE
         RMR=4.6E+2/(FMHZ**1.5)
         XMR=3.0E+4/(FMHZ)
         RSR=0.25
         A=SQRT((REZOR/(RAR+RCR+RMR+RSR)))
      END IF
      WRITE(1,810)RMR,XMR
  810 FORMAT(2X,'9  RMR= ',E10.4,' (OHMS)',14X,
     6 '10 XMR= ',E10.4,' (OHMS)')
      WRITE(1,811)A,RSR
  811 FORMAT(1X,'11 A= ',E10.4,' (-----)',16X,
     6 '12 RSR= ',E10.4,' (OHMS)'/)
      WRITE(1,812)
  812 FORMAT(1X,'RECEIVER NOISE')
      WRITE(1,813)FO,RN
  813 FORMAT(1X,'13 FO= ',E10.4,' (-----)',15X,
     6 '14 RN= ',E10.4,' (OHMS)')
      WRITE(1,814)GNO,BNO
  814 FORMAT(1X,'15 GNO= ',E10.4,' (MHOS)',15X,
     6 '16 BNO= ',E10.4,' (MHOS)'/)
      WRITE(1,815)
  815 FORMAT(1X,'TRANSMISSION LINE')
      WRITE(1,816)REZOR,IMZOR
  816 FORMAT(1X,'17 REZOR= ',E10.4,' (OHMS)'
     6 ,13X,'18 IMZOR= ',E10.4,' (OHMS)')
      WRITE(1,817)ALPHAR,BETAR
  817 FORMAT(1X,'19 ALPHAR= ',E10.4,' (NEPERS/METER)',4X,'20 BETAR= '
     6 ,E10.4,' (NEPERS/METER)')
      WRITE(1,818)DR
  818 FORMAT(1X,'21 DR= ',E10.4,' (METERS)'/)
C     ****************************************************************
C     * I=AREA, J=FREQUENCY RANGE                                    *
C     * 1=BUSINESS,2=RESIDENTIAL,3=RURAL     1=(20-48)MHZ, 2=(48-102)MHZ  *
C     ****************************************************************
```

II C. Listing

```
C        *******************************************************
C        *     PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE      *
C        *******************************************************
C
         REAL K, IMZOR, LCR, LMR, AN, LNR, NSTD
         COMPLEX ZOR, YNO, GAMMAR, ZOUT, YS, REFLR
         CHARACTER*65 B3, C3, D3, E3, F3, G3
C
C        ****SONF.DAT IS THE DATA FILE, SONF.OUT IS THE OUTPUT FILE****
C
         OPEN(UNIT=3, TYPE='OLD', NAME='SONF.DAT')
         OPEN(UNIT=1, TYPE='NEW', NAME='SONF.OUT')
         WRITE(1,10)
         READ(3,5)B3
         READ(3,6)C3,D3
         READ(3,7)E3,F3
         READ(3,8)G3
    5    FORMAT(A65)
    6    FORMAT(2A20)
    7    FORMAT(2A35)
    8    FORMAT(A35)
   10    FORMAT(1H1,'PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE  1/13/84'
     1   ,2X,'PAGE 1')
         WRITE(1,20)B3
   20    FORMAT(1X,'SCENARIO: ',1X,A65,1X)
         WRITE(1,25)C3
   25    FORMAT(11X,A40)
   35    FORMAT(11X,A40/)
         WRITE(1,25)D3
         WRITE(1,25)E3
         WRITE(1,25)F3
         WRITE(1,35)G3
   75    FORMAT(5F10.4)
  100    FORMAT(6F10.4)
         READ(3,75)FMHZ,B,TC,TM,TN
         READ(3,100)FO,RN,GNO,BNO,REZOR,DR
C        ***********************WRITE INPUT VARIABLES*******************
C
         WRITE(1,200)
  200    FORMAT(24X,'INPUT VARIABLES,TABLE 1'/)
         WRITE(1,225)
  225    FORMAT(1X,'FREQUENCY')
         WRITE(1,300)FMHZ,B
  300    FORMAT(1X,'1  FMHZ= ',E10.4,' (MHZ)',16X,'2  B= ',E10.4,' (HZ)'/)
         WRITE(1,305)
  305    FORMAT(1X,'TEMPERATURE')
         WRITE(1,325)TC,TM
  325    FORMAT(1X,'3  TC= ',E10.4,' (DEG K)',16X,
     5   '4  TM= ',E10.4,' (DEG K)')
         WRITE(1,330)TN
  330    FORMAT(1X,'5  TN= ',E10.4,' (DEG K)'/)
         WRITE(1,335)
  335    FORMAT(1X,'ANTENNA')
C
C        ********************CALCULATE FMEAN(<F>)*********************
C
         TO=2.88E+2
         K=1.38E-23
```

II B. Files

SONF.FTN is the FORTRAN source code file. The input and output files are SONF.DAT and SONF.OUT, respectively. By typing

```
>RUN SONF <cr>
```

input data will be read from SONF.DAT and output data will be written to SONF.OUT.

Each time SONF is executed, successive version numbers of SONF.OUT are created. These are accessed by specifying the desired version number and will remain in the directory until they are purged.

SONF.FTN, the FORTRAN source code file; SONF.LIST, the FORTRAN listing file; and SONF.TSK have been stored on a backup tape under the label SONF using the DEC utility copy. The following sequence of commands allow files to be read from the backup tape:

```
>ALLOC MSO: <cr>
>MC MOU MSO:  SONF <cr>
>copy <cr>
>From:  MSO:  FILENAME, FILETYPE <cr>
>To:  DRO:  [200,244] <cr>
>DIS MSO:
  <cr>:  carriage return
```

TABLE II-4

Numerical Values, Input Variables (cont.)

environmental noise (cont.)

Appendix G

NO.	ALGEBRAIC SYMBOL	NUMERICAL VALUES		UNITS
24	$D_{\ell,F_{a,t}}$	$7.6 + 0.0179\ (f_{MHz}-20)$, 20-48 MHz	business area	dB
		$8.1 - 0.44\ (f_{MHz}-48)$, 48-102 MHz		
		$6.5 + 0.021\ (f_{MHz}-20)$, 20-48 MHz	residential area	
		$7.1 - 0.042\ (f_{MHz}-48)$, 48-102 MHz		
		$5.5 - 0.132\ (f_{MHz}-20)$, 20-48 MHz	rural area	
		$1.8 + 0.024\ (f_{MHz}-48)$, 48-102 MHz		
25	$\sigma_{F_{a,\ell}}$	$4.93 + 0.079\ (f_{MHz}-20)$, 20-48 MHz	business area	dB
		$7.13 + 0.030\ (f_{MHz}-48)$, 48-102 MHz		
		$4.65 - 0.024\ (f_{MHz}-20)$, 20-48 MHz	residential area	
		$3.98 - 0.023\ (f_{MHz}-48)$, 48-102 MHz		
		$4.53 - 0.046\ (f_{MHz}-20)$, 20-48 MHz	rural area	
		$3.23 - 0.0109\ (f_{MHz}-48)$, 48-102 MHz		

TABLE II-4

Numerical Values, Input Variables (cont.)

	NO.	ALGEBRAIC SYMBOL	NUMERICAL VALUES	UNITS
transmission line — Appendix F	17	Re(zor)	50	ohms
	18	Im(zor)	$1.25 \times 10^{-2} - 2.65(f_{MHz})^{-1/2}$	ohms
	19	α_r	$1.68 \times 10^{-3}(f_{MHz})^{1/2} + 8.0 \times 10^{-6} f_{MHz}$	nepers/m
	20	β_r	$3.18 \times 10^{-2} f_{MHz}$	nepers/m
	21	d_r	10	m
environmental noise — Appendix G	22	$\langle F_a \rangle$	$67.2 - 27.7 \log_{10} f_{MHz}$, rural areas $72.5 - 27.7 \log_{10} f_{MHz}$, residential areas $76.8 - 27.7 \log_{10} f_{MHz}$, business areas	dB
	23	$D_{u,F_{a,t}}$	$10.5 + 0.093\ (f_{MHz}-20)$, 20-48 MHz; $13.1 - 0.022\ (f_{MHz}-48)$, 48-102 MHz — business area $10.6 + 0.061\ (f_{MHz}-20)$, 20-48 MHz; $12.3 + 0.0037\ (f_{mHz}-48)$, 48-102 MHz — residential area $7.8 - 0.089\ (f_{MHz}-20)$, 20-48 MHz; $5.3 + 0.096\ (f_{MHz}-48)$, 48-102 MHz — rural area	dB

TABLE II-4

Numerical Values, Input Variables (cont.)

	NO.	ALGEBRAIC SYMBOL	NUMERICAL VALUES	UNITS
matching network, Appendix D	9	$r_{m,r}$	$4.6 \times 10^2/f_{MHz}^{3/2}$, with matching network; 0, no matching network	ohms
	10	$x_{m,r}$	$3.0 \times 10^4/f_{MHz}$, with matching network; 0, no matching network	ohms
	11	a	$[Re(z_{or})/(r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r})]^{1/2}$, with matching network; 1, no matching network	—
	12	$r_{s,r}$	0.25, with matching network; 0, without matching network	ohms
receiver noise, Appendix E	13	f_o	5.0	—
	14	r_n	100	ohms
	15	g_{no}	2.0×10^{-2}	mhos
	16	b_{no}	0	mhos

TABLE II-4

Numerical Values, Input Variables

	NO.	ALGEBRAIC SYMBOL	NUMERICAL VALUES	UNITS
frequency, Appendix A	1	f_{MHz}	30, 50, 88	MHz
	2	b	1.7×10^{4}	Hz
temperature, Appendix B	3	t_c	2.88×10^{2}	deg K
	4	t_m	2.88×10^{2}	deg K
	5	t_n	2.88×10^{2}	deg K
antenna, Appendix C	6	$r_{c,r}$	$1.939 \times 10^{-4} \sqrt{f_{MHz}}$	ohms
	7	$r_{a,r}$	$2.84 \times 10^{-4}\ f^{2}_{MHz}$	ohms
	8	$x_{a,r}$	$-3.0 \times 10^{-4}/f_{MHz}$	ohms

TABLE II-3

DERIVED VARIABLES, SYSTEM OPERATING NOISE FIGURE (cont.)

NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION AND DERIVATION	UNITS
19	$\langle F \rangle$	FMEAN	expected value of operating noise figure of the receiving system $= 10 \left[\log_{10} \langle f \rangle - \frac{1}{2} (\sigma_F/10)^2 \ln 10\right]$	dB
20	$\langle \Delta F \rangle$	DFMEAN	expected value of receiver system noise degradation figure $= \langle F \rangle - \langle F_a \rangle$	dB
21	$\langle f/f_a \rangle$	SDFMEAN	expected value of receiver system noise degradation factor $= \langle f \rangle / \langle f_a \rangle$	—
22	$\langle N \rangle$	NMEAN	expected value of system available noise power referred to the output terminals of the equivalent lossless receiving antenna $= W + \langle F \rangle$	dBm
23	σ_N	NSTD	standard deviation of operating noise figure of the receiving system $= \sigma_F$	dB

TABLE II-3

DERIVED VARIABLES, SYSTEM OPERATING NOISE FIGURE (cont.)

NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION AND DERIVATION	UNITS
13	$\ell_{c,r}$	LCR	available loss factor of the receiving antenna = reciprocal of the receiving antenna efficiency $= (r_{a,r} + r_{c,r})/r_{a,r}$	—
14	$\ell_{m,r}$	LMR	available loss factor of the receiving antenna matching network = reciprocal of the matching network efficiency $= (r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r})/(r_{a,r} + r_{c,r})$	—
15	$\ell_{n,r}$	LNR	available loss factor of the receiving transmission line = reciprocal of the receiving transmission line efficiency $= \frac{e^{2\alpha_r d_r}\left\{1 - \lvert\Gamma_r\rvert^2 e^{-4\alpha_r d_r} - 2[\mathrm{Im}(z_{or})/\mathrm{Re}(z_{or})]\ \mathrm{Im}(\Gamma_r e^{-2\gamma_r d_r})\right\}}{1 - \lvert\Gamma_r\rvert^2 - 2[\mathrm{Im}(z_{or})/\mathrm{Re}(z_{or})]\ \mathrm{Im}(\Gamma_r)}$	—
16	$\langle f \rangle$	SFMEAN	expected value of operating noise factor of the receiving system $= \langle f_a \rangle + (\ell_{c,r} - 1)(t_c/t_{ref}) + \ell_{c,r}(\ell_{m,r} - 1)(t_m/t_{ref})$ $+ \ell_{c,r}\ell_{m,r}(\ell_{n,r} - 1)(t_n/t_{ref}) + \ell_{c,r}\ell_{m,r}\ell_{n,r}(f_r - 1)$	—
17	σ_f	SFSTD	standard deviation of operating noise factor of the receiving system $= \sigma_{f_a}$	—
18	σ_F	FSTD	standard deviation of operating noise figure of the receiving system $= 10\left\{(1/\ln 10)\log_{10}\left[1 + (\sigma_f^2/\langle f \rangle^2)\right]\right\}^{1/2}$	dB

TABLE II-3

DERIVED VARIABLES, SYSTEM OPERATING NOISE FIGURE (cont.)

NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION AND DERIVATION	UNITS
7	y_{no}	YNO	complex empirical receiver noise parameter with the dimensions of admittance $= g_{no} + jb_{no}$	mhos
8	f_r	FR	receiver noise factor for a source admittance y_s $= f_o + \frac{r_n}{Re(y_s)} \quad \lvert y_s - y_{no} \rvert^2$	—
9	$\sigma_{F_{a,t}}$	FATSTD	standard deviation of time variability of external noise figure of receiving antenna $= \left(\frac{1}{1.28}\right) \left[\frac{1}{2} (D^2_{u,F_{a,t}} + D^2_{\ell,F_{a,t}}) - \frac{1}{2\pi} (D_{u,F_{a,t}} - D_{\ell,F_{a,t}})^2\right]^{1/2}$	dB
10	σ_{F_a}	FASTD	standard deviation of external noise figure of receiving antenna $= \left[\sigma^2_{F_{a,\ell}} + \sigma^2_{F_{a,t}}\right]^{1/2}$	dB
11	$\langle f_a \rangle$	SFAMEAN	expected value of external noise factor of receiving antenna $= 10^{\left[(\langle F_a \rangle/10) + \frac{1}{2} (\sigma_{F_a}/10)^2 \ln 10\right]}$	—
12	σ_{f_a}	SFASTD	standard deviation of external noise factor of receiving antenna $= \langle f_a \rangle \cdot \left[10^{(\sigma_{F_a}/10)^2 \ln 10} - 1\right]^{1/2}$	—

TABLE II-3

DERIVED VARIABLES, SYSTEM OPERATING NOISE FIGURE

NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION AND DERIVATION	UNITS
1	W	W	system reference noise power $= 30 + 10 \log_{10} (kt_{ref} b)$	dBm
2	z_r	ZR	input impedance to the receiving antenna with its matching network $= a^2 \left[(r_{a,r}+r_{c,r}+r_{m,r}+r_{s,r}) + j(x_{a,r} + x_{m,r})\right]$	ohms
3	z_{or}	ZOR	complex characteristic impedance of the receiving transmission line $= Re(z_{or}) + j\, Im(z_{or})$	ohms
4	Γ_r	REFLR	complex voltage reflection coefficient at the output of the receiving antenna matching network $= (z_r - z_{or})/(z_r + z_{or})$	—
5	γ_r	GAMMAR	complex propagation constant of the receiving transmission line $= \alpha_r + j\beta_r$	nepers/m
6	y_s	YS	complex source admittance of the receiver $= \frac{1}{z_{or}} \; \frac{1 - \Gamma_r e^{-2\gamma_r d_r}}{1 + \Gamma_r e^{-2\gamma_r d_r}}$	mhos

TABLE II-2

CONSTANTS, SYSTEM OPERATING NOISE FIGURE

NO.	ALGEBRAIC SYMBOL	COMPUTER SYMBOL	DEFINITION	VALUE	UNITS
1	t_{ref}	TO	reference noise temperature	2.88×10^{2}	deg K
2	k	K	Boltzmann's constant	1.38×10^{-23}	J/deg K

```
    4   ' (-----)'/)
        WRITE(1,883)LNR
883     FORMAT(1X,'15 LNR= ',E10.4,' (-----)'/)
        WRITE(1,884)SFMEAN
884     FORMAT(1X,'16 SFMEAN= ',E10.4,' (-----)'/)
        WRITE(1,885)SFSTD,FSTD
885     FORMAT(1X,'17 SFSTD= ',E10.4,' (-----)',10X,'18 FSTD= ',E10.4,
    5   ' (dB)'/)
        WRITE(1,886)FMEAN,DFMEAN
886     FORMAT(1X,'19 FMEAN= ',E10.4,' (dB)',13X,
    5   '20 DFMEAN= ',E10.4,' (dB)'/)
        WRITE(1,887)SDFMEN,AN
887     FORMAT(1X,'21 SDFMEAN= ',E10.4,' (-----)',8X,
    5   '22 NMEAN= ',E10.4,' (dBm)'/)
        WRITE(1,890)NSTD
890     FORMAT(1X,'23 NSTD= ',E10.4,' (dB)'/)
        CLOSE(UNIT=1,DISP='SAVE')
        CLOSE(UNIT=3)
        STOP
        END
```

APPENDIX III

PROGRAM SONF INPUT PARAMETERS: VHF-FM RECEIVING SYSTEM WITH AN ELECTRICALLY-SHORT MONOPOLE ANTENNA

CONTENTS

III A. Frequency Parameters: f_{MHz}, b

Frequency, f_{MHz}

The frequency band of interest is the VHF-FM band 30-88 MHz. Particular frequencies of interest are 30, 50, and 88 MHz which correspond on a $\log_{10}$ scale to the lower, middle, and upper frequencies of the band.

Noise Power Effective Bandwidth, b

Nominal bandwidth characteristics are:

Channel spacing - 25 kHz

Occupied bandwidth - 99 percent of the emitted spectral components falls within a bandwidth of less than 19 kHz

IF bandwidth - 17 kHz, 3 dB bandwidth

The noise power effective bandwidth b is approximately equal to the 3 dB IF bandwidth. Accordingly, b = 17 kHz.

III B. Ambient Temperature Parameters: t_c, t_m, t_n

The ambient temperatures t_c, t_m and t_n of the antenna, matching network, and transmission line, respectively, are normally not appreciatively different from the reference noise temperature t_{ref} = 288 deg K. The reference noise temperature t_{ref} is set equal to 288 deg K because measurements of man-made environmental noise are usually referred to a terminal noise temperature of 288 deg K.[1]

Accordingly, $t_c = t_m = t_n = t_{ref} = 288$ deg K.

III C: Antenna Parameters: $r_{a,r}$, $x_{a,r}$, $r_{c,r}$

Consider a cylindrical monopole antenna of height h and radius a_o over an infinitely conducting ground plane of infinite extent (see fig.(III-1). Assume that the antenna geometry satisfies the following conditions:

$$\frac{2\pi h}{\lambda} << 1 \quad \text{(electrically short)} \tag{III-1a}$$

$$\frac{2\pi a_o}{\lambda} << 1 \quad \text{(electrically thin)} \tag{III-1b}$$

$$a_o/h << 1 \quad \text{(geometrically thin)} \tag{III-1c}$$

This antenna is selected for consideration because its input impedance properties are well known. If there is no top loading, then the current distribution I(z,t) is given by:

$$I(z,t) = \begin{cases} I_m \sin[\beta(h - z)] \cos \omega t, & 0 \leq z \leq h \\ I_m \sin[\beta(h + z)] \cos \omega t, & -h \leq z \leq 0 \end{cases}$$

$$\approx \begin{cases} I(0)\ (1 - \frac{z}{h}) \cos \omega t, & 0 \leq z \leq h \\ I(0)\ (1 + \frac{z}{h}) \cos \omega t, & -h \leq z \leq 0 \end{cases} \tag{III-2}$$

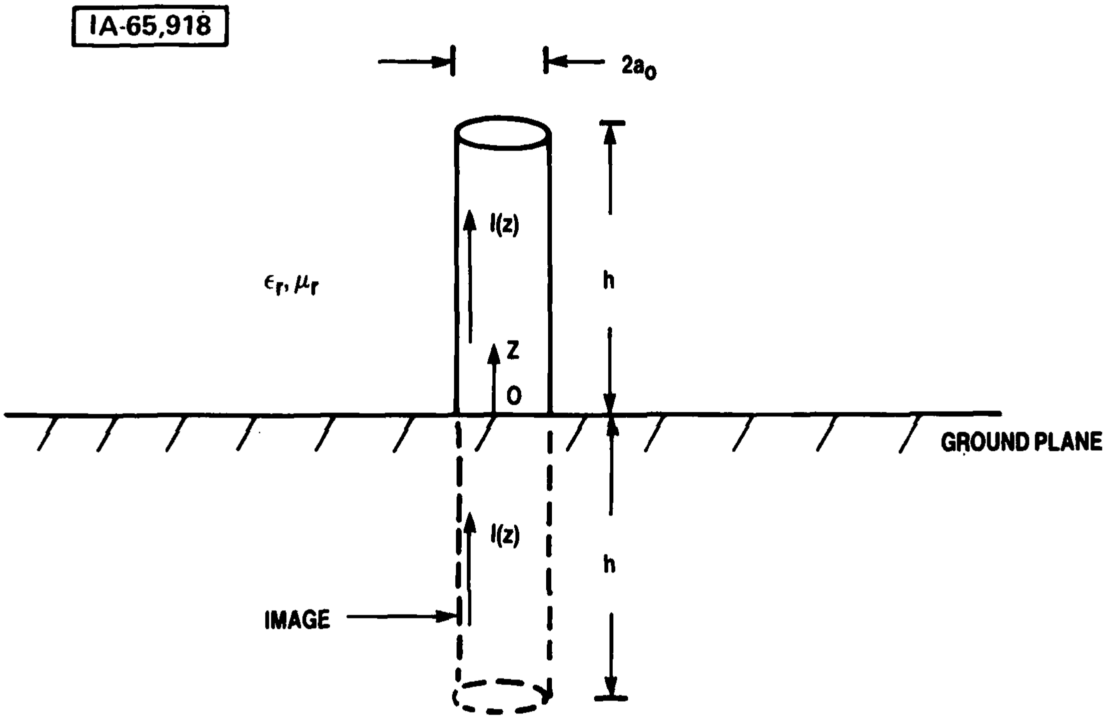

Figure III-1. Monopole over Groundplane of Infinite Extent

where

$$I(0) = I_m \sin(\beta h)$$

$$\beta = \omega \sqrt{\epsilon\mu} = 2\pi/\lambda = (2\pi/\lambda_o) \sqrt{\epsilon_r \mu_r}$$

λ_o = wavelength in free space

μ_r, ϵ_r = relative permeability, permittivity, respectively, of homogeneous medium in which monopole is imbedded.

The input impedance equivalent circuit of the antenna and its matching network is shown in fig. 2 of Section 2.

Radiation Resistance, $r_{a,r}$

The radiation resistance $r_{a,r}$, with respect to the peak base current I(0), for a sinusoidal current waveform with a triangular spatial distribution, is given by[2]

$$r_{a,r} = \frac{2\overline{P_{total}}}{I^2(0)} = \sqrt{\frac{\mu_r}{\epsilon_r}}\, 40\pi^2 \left(\frac{h}{\lambda}\right)^2$$

$$= \sqrt{\frac{\mu_r}{\epsilon_r}}\, 40\pi^2 \;\epsilon_r \mu_r \left(\frac{h}{\lambda_o}\right)^2$$

$$= \mu_r^{3/2}\, \epsilon_r^{1/2}\, 40\pi^2 (h/\lambda_o)^2 \qquad \text{(III-3)}$$

Input Reactance, $x_{a,r}$

The input reactance $x_{a,r}$, with respect to the peak base current I(0), or conditions (III-1), is given inconsistently in the literature by [3] – [5]

$$x_{a,r} = \frac{-60}{\beta h}\sqrt{\frac{\mu_r}{\epsilon_r}}\left[\ln\left(\frac{h}{a_o}\right) \pm 1\right] = -\frac{30}{\pi}\left(\frac{\lambda_o}{h}\right)\frac{1}{\epsilon_r}\left[\ln\left(\frac{h}{a_o}\right) \pm 1\right] \quad \text{(III-4)}$$

where the positive sign corresponds to References [3], [4] and the negative sign corresponds to Reference [5].

The input series capacitance C corresponding to Eq.(III-3) is given by

$$C = -\frac{1}{x_{a,r}\omega} = -\frac{\lambda_o}{2\pi}\sqrt{\epsilon_o\mu_o}\left(-\frac{\pi}{30}\frac{h}{\lambda_o}\right)\frac{\epsilon_r}{\ln\left(\frac{h}{a_o}\right) \pm 1}$$

$$= \frac{h\epsilon_r}{60 \times 3 \times 10^8}\;\frac{1}{\ln\left(\frac{h}{a_o}\right) \pm 1} = \frac{55.6\ \epsilon_r h}{\ln\left(\frac{h}{a_o}\right) \pm 1}\ \text{pf} \quad \text{(III-5)}$$

The series capacitance C is approximately equal to the quasi-static series capacitance of the antenna [6].

Eq.(III-3) neglects the shunt capacitance between the antenna and the ground plane. The shunt capacitance reduces the current delivered to the antenna and therefore reduces the power radiated by the antenna.

Ohmic Loss Resistance, $r_{c,r}$

The ohmic loss resistance $r_{c,r}$, for a current of sinusoidal temporal waveform and triangular spatial distribution, is given by [7],[8]

$$r_{c,r} = \frac{2\,\overline{P_{ohmic}}}{I^2(0)} = \frac{2\,R_s}{I^2(0)\;2\pi a_o}\int_0^h \overline{I^2(z)}\,dz$$

$$= \frac{2\,R_s}{I^2(0)\;2\pi a_o}\;\frac{I^2(0)}{2}\int_0^h \left(1-\frac{z}{h}\right)^2 dz$$

$$= \frac{R_s}{2\pi a_o}\;\frac{h}{3} \quad = \frac{h}{6a_o}\left(\frac{\mu_r}{\pi\lambda_o\sigma\;\epsilon_o}\right)^{1/2} \qquad \text{(III-6)}$$

where

P_{ohmic} = time-averaged ohmic loss of antenna (watts)

R_s = surface resistivity (ohms/square) = $(\pi\mu_r/\epsilon_o\;\lambda_o\;\sigma_{DC})^{1/2}$

σ_{DC} = DC conductivity (mhos/meter)

μ_r = relative permeability of conductor (——)

ϵ_o = permittivity of free space (farads/meter)

Numerical Example

Consider a monopole antenna whose parameters have the following numerical values:

h = 10 inches = 0.254 meters

a_o = 0.714 inches = 0.01814 meters

$\mu_r = \epsilon_r = 1$

copper conductor ($\sigma_{DC} = 5.8 \times 10^7$ mhos/meter,

$R_s = 2.61 \times 10^{-7} \sqrt{f}$ ohms).

For these numerical values, Eqs. (III-3), (III-4), and (III-6) reduce to

$$r_{a,r} = 2.84 \times 10^{-4} f^2_{MHz} \text{ (ohms)} \qquad \text{(III-7)}$$

$$\begin{aligned} x_{a,r} &= -(2.97 \times 10^4)(1 \pm 0.38)/f_{MHz} \\ &\approx -3.0 \times 10^4/f_{MHz} \text{ (ohms)} \end{aligned} \qquad \text{(III-8)}$$

$$r_{c,r} = 1.939 \times 10^{-4} \sqrt{f_{MHz}} \text{ (ohms)} \qquad \text{(III-9)}$$

The value h = 10 inches corresponds to a VHF-FM antenna which can be packaged inside a standard airborne blade configuration. The value a_o = 0.714 inches is chosen as that h/a_o = 14 and the Ref. [5] parameter $\Omega = 2 \ln (2h/a_o) = 6.66$. In Ref. [5], Ω =7 is

the lowest value for which Eq. (6c) of Ref. [5] is evaluated. Lower values of Ω correspond to fatter antennas and larger errors in the application of Eq. (6c) to estimating monopole input reactance.

III D. Impedance Matching Network Parameters: x_{mr}, $r_{m,r}$, a, $r_{s,r}$

Reactance, $x_{m,r}$

The reactance of the inductive matching network should be designed to be equal to the conjugate of that of the dipole antenna input reactance $x_{a,r}$. Accordingly,

$$x_{m,r} = j\omega L = \begin{cases} -x_{a,r}, & \text{with matching network} \\ 0, & \text{no matching network} \end{cases} \qquad \text{(III-10)}$$

where L is the inductance of the matching network.

Coil Ohmic Loss Resistance, $r_{m,r}$

Consider a single layer solenoid of n turns whose unwound length is much less than a wavelength.

The inductance L is given , pproximately by[9]

$$L = n^2[d^2/(18d + 40\ell)] \quad \text{(mircohenries)} \qquad \text{(III-11)}$$

where

ℓ = length of solenoid axis (inches)

d = diameter of solenoid (inches)

The unloaded quality factor Q_m, for solenoids whose diameter is sufficiently small so that its ohmic loss resistance is much larger than the radiation loss resistance, is given approximately by

$$Q_m = A\ d\ f_{MHz}^{1/2} \qquad \text{(III-12)}$$

where

A = ordinate of Figure (III-2)

d = form (solenoid) diameter (inches)

f = frequency (MHz)

Eq.(III-12) includes induced e.m.f. proximity effects on ohmic loss. The coefficient A is approximately proportional to the number of turns n because the stored energy is proportional to n^2 and the ohmic loss is proportional to n. The quality factor Q_m is proportional to (frequency)$^{1/2}$ because the stored energy is proportional to f and the ohmic loss is proportional to $f^{1/2}$.

The coil ohmic loss resistance $r_{m,r}$ is given by

$$r_{m,r} = \begin{cases} x_{m,r}/Q_m, & \text{with matching network} \\ 0, & \text{no matching network} \end{cases} \qquad \text{(III-13)}$$

where $x_{m,r}$ is given by Eq.(III-10) and Q_n is given by Eq.(III-12).

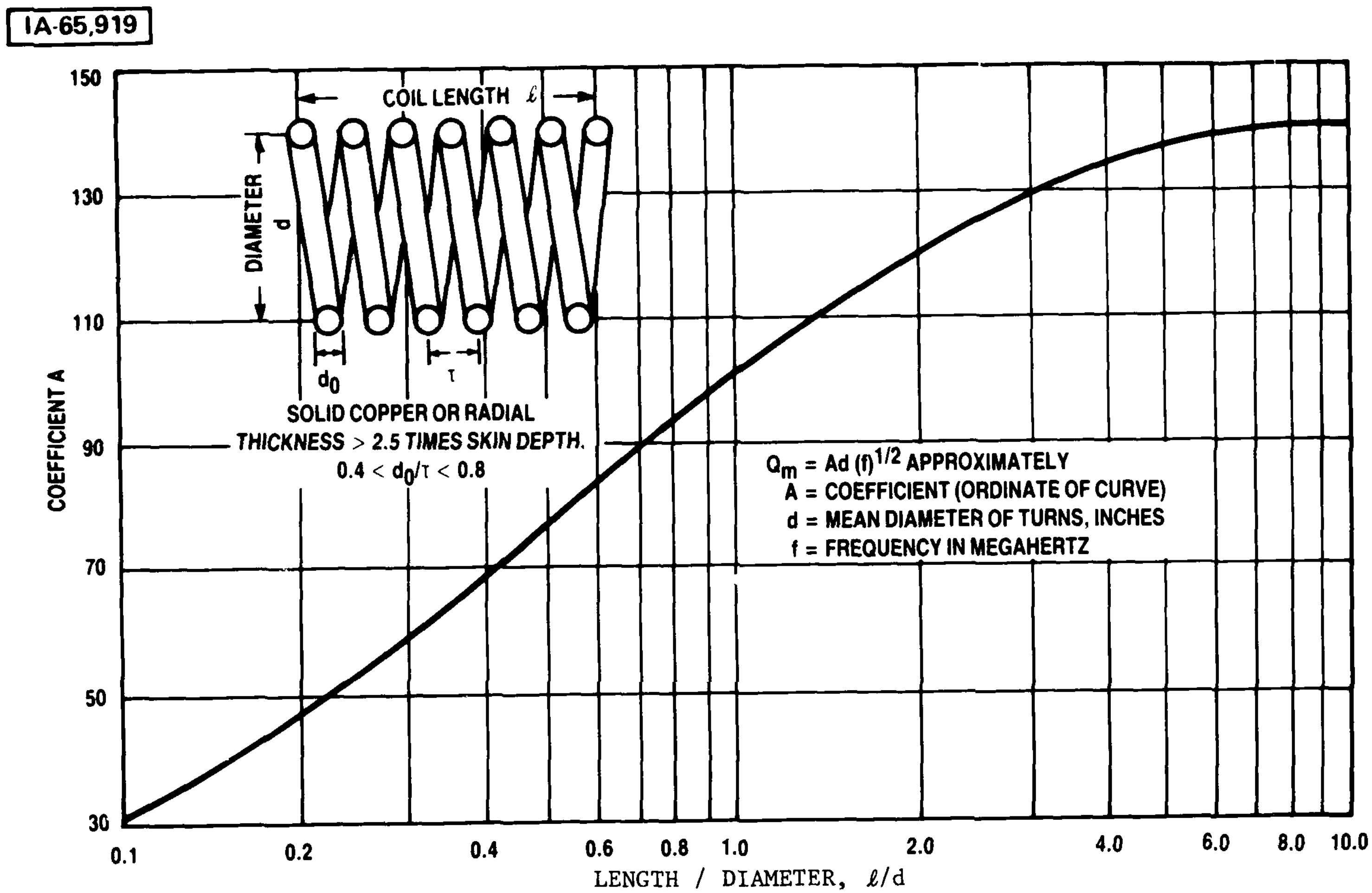

Figure III-2. C_m of Unshielded Coil
[After ITT, "Reference Data for Radio Engineers," (Howard Sams & Co., Indianapolis, Md., 5th Ed., 1970), p. 6-4].

AD-A159 070 EFFECT OF ANTENNA IMPEDANCE MISMATCH ON THE SIGNAL-TO-NOISE RATION OF A RADIO RECEIVING SYSTEM(U) MITRE CORP BEDFORD MA M M WEINER MTR-9221 2/2

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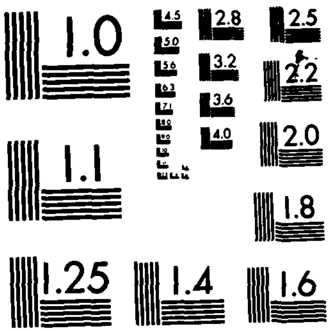

Transformer turns ratio, a

Consider a low-loss transmission line of characteristic impedance z_{or} which is connected to the secondary of the ideal transformer of the antenna matching network. The voltage reflection coefficient Γ_r at the transmission line is given by

$$\Gamma_r = \frac{z_{out} - z_{or}}{z_{out} + z_{or}} \qquad \text{(III-14)}$$

where

$$z_{out} = a^2[(r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r}) + j(x_{a,r} + x_{m,r})]$$

For $\Gamma_r = 0$ and $z_{or} \approx R_e(z_{or})$,

$$x_{m,r} = -x_{a,r} \qquad \text{(III-15)}$$

$$a = [R_e(z_{or})/(r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r})]^{1/2} \qquad \text{(III-16)}$$

In the absence of a matching network,

$$a = 1 \qquad \text{(III-17)}$$

Switch Ohmic Loss Resistance, $r_{s,r}$

The ohmic loss resistance of the switch depends upon the number of series and parallel switches in the circuit and whether they are located on the primary or secondary side of the ideal transformer. If the series resistance of each switch is R_{switch}, then for k

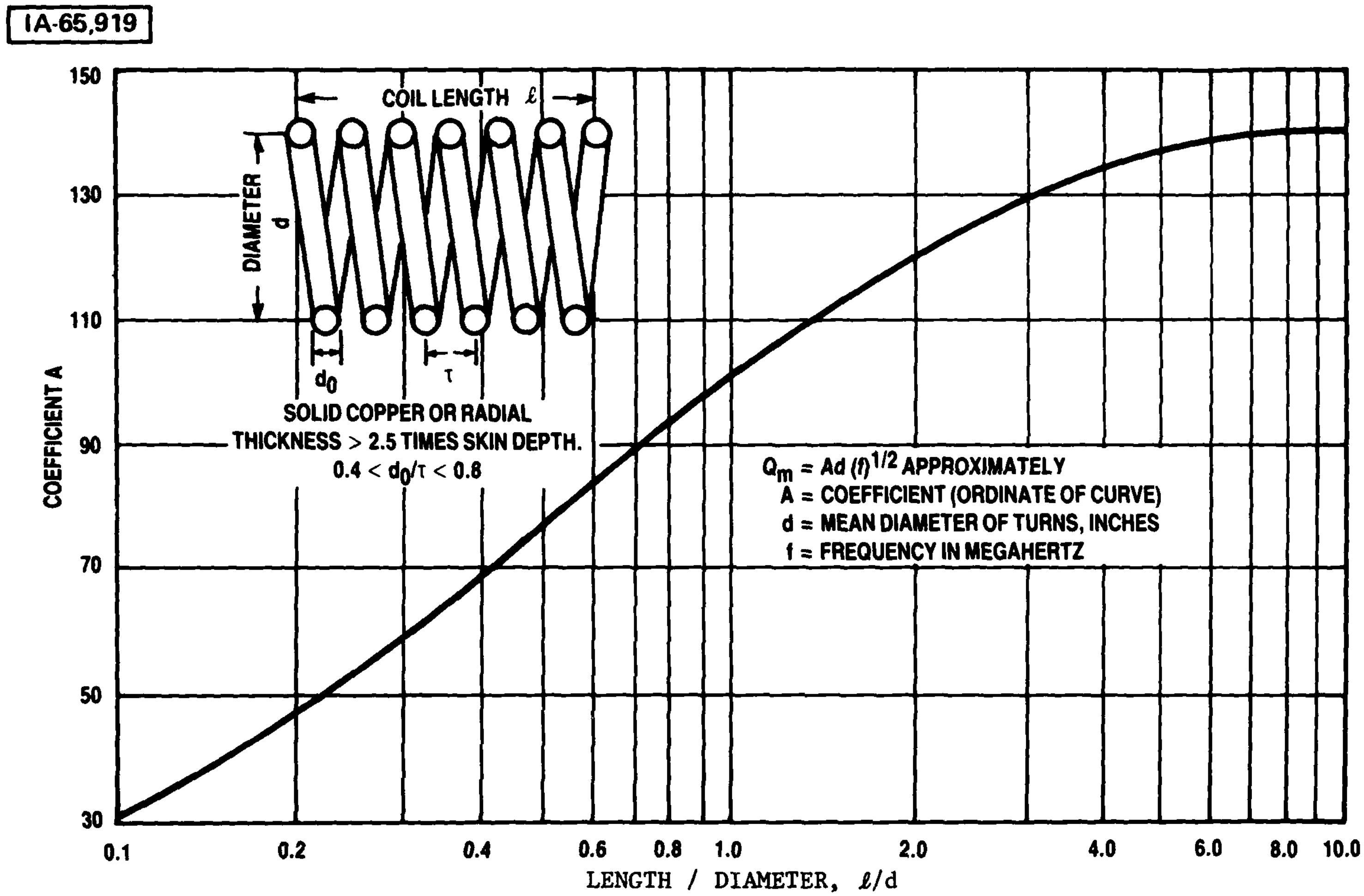

Figure III-2. Q_m of Unshielded Coil
[After ITT, "Reference Data for Radio Engineers," (Howard Sams & Co., Indianopolis, Md., 5th Ed., 1970), p. 6-4].

switches in parallel,

$$r_{s,r} = \begin{cases} R_{switch}/k, & \text{k switches located on secondary side of ideal transformer} \\ (R_{switch}/ka^2), & \text{k switches located on primary side of ideal transformer.} \end{cases} \qquad \text{(III-18)}$$

where a is the transformer turns ratio.

Numerical Example

From Eq.(III-4) and Eq. (III-10).

$$x_{m,r} = \begin{cases} 3.0 \times 10^4/f_{MHz}, & \text{with matching network} \\ 0, & \text{no matching network} \end{cases} \qquad \text{(III-19)}$$

Consider a single layer solenoid of diameter d = 0.5 inches and length ℓ. From Fig.(III-2), Q_m of the solenoid increases with increasingly values of ℓ/d and levels off for $\ell/d \approx 3.0$. Let ℓ = 1.5 inches. In Eq.(III-12) the coefficient A = 130 for ℓ/d = 3.0. From Eq.(III-12),

$$Q_m = 130 \times 0.5 \times f_{MHz}^{1/2} = 65\ f_{MHz}^{1/2} \qquad \text{(III-20)}$$

At 30 MHz, Q_m = 356. A more exact formulation(10) gives Q_m = 380.

The inductance L is given by

$$L = \frac{x_{m,r}}{2\pi f} = \frac{3.0 \times 10^4/f_{MHz}}{2\pi \times 10^6/f_{MHz}} = \frac{4.77 \times 10^3}{f_{MHz}^2} \ (\mu h) \tag{III-21}$$

At 30 MHz, L = 5.3 μh. From Eq.(III-11), the number of turns n is given by $n = \frac{1}{d}\left[L(18d + 40\ell)\right]^{1/2}$ = 38.2 turns at 30 MHz. This number of turns can be packaged in an axial length ℓ = 1.5 inches so that the conductor diameter is much larger than the skin depth. The ohmic loss of the solenoid is given by Eq.(III-13) to be

$$r_{m,r} = \begin{cases} 4.6 \times 10^2/f_{MHz}^{3/2}, & \text{with matching network} \\ 0, & \text{no matching network} \end{cases} \tag{III-22}$$

At 30 MHz, $r_{m,r}$ = 2.8 ohms.

For a P-I-N diode switch (Unitrode Model UM7200, dc forward current bias of 100 ma), the series resistance R_{switch} = 0.25 ohms. For present purposes, assume that the switching network consists of a single switch which is located on the secondary side of the transformer. From Eq.(III-18), for k = 1.

$$r_{s,r} = R_{switch} = 0.25 \text{ ohms} \tag{III-23}$$

The efficiency η, of the antenna with its matching and switching networks, is given by

$$\eta = \frac{r_{a,r}}{r_{a,r} + r_{c,r} + r_{m,r} + r_{s,r}} = \frac{1}{1 + \frac{r_{c,r} + r_{s,r}}{r_{a,r}} + \frac{r_{m,r}}{r_{a,r}}}$$

$$= \frac{1}{1 + \frac{r_{c,r} + r_{s,r}}{r_{a,r}} + \frac{Q_o}{Q_m}} \qquad \text{(III-24)}$$

where, for impedance-matching conditions,

$$\frac{r_{m,r}}{r_{a,r}} \equiv \frac{|x_{m,r}|}{r_{a,r}\, Q_m} = \frac{|x_{a,r}|}{r_{a,r}\, Q_m} = \frac{Q_o}{Q_m}$$

Q_o = antenna quality factor $\equiv |x_{a,r}|/r_{a,r}$

Q_m = matching network quality factor $\equiv |x_{m,r}|/r_{m,r}$

At 30 MHz for the above example, $r_{a,r}$ = 0.25 ohms, $r_{c,r} = 1.05 \times 10^{-3}$ ohms, $r_{m,r}$ = 2.8 ohms, $r_{s,r}$ = 0.25 ohms, $Q_o = 3.9 \times 10^3$, and $Q_m = 3.8 \times 10^2$. Accordingly,

$$\eta = .0774 = -11.1 \text{ dB} \qquad \text{(III-25)}$$

The poor efficiency, given by Eq. (III-25), results mostly from ohmic loss in the impedance-matching network.

III E Receiver Noise Parameters: f_o, r_n, g_{no}, b_{no}

The receiver noise factor f_r for an arbitrary source admittance y_s is given by[(11),(12)]

$$f_r = f_o + \frac{r_n}{R_e(y_s)} \left| y_s - (g_{no} + jb_{no}) \right|^2 \qquad \text{(III-26)}$$

<u>Minimum Noise Factor, f_o</u>

The receiver noise factor f_r has a minimum value f_o when the source admittance y_s (looking back at the transmission line) is $y_s = g_{no} + jb_{no}$. Assume that the receiver is designed to have a minimum noise factor f_o when $y_s = y_{so} = 20 \times 10^{-3}$ mhos corresponding to a source impedance $z_s = z_{so} = 50$ ohms.

The predetection noise equivalent power p_n at the input to the receiver is given by

$$\begin{aligned} p_n &= kt_{ref} b\, f_r \qquad \text{(III-27)} \\ &= kt_{ref} b\, f_o, \qquad y_s = y_{so} = 20 \times 10^{-3} \text{ mhos} \end{aligned}$$

where

$kt_{ref}b$ = reference noise power

$$= 1.38 \times 10^{-23}\ \mathrm{J/^oK} \times 288\ \mathrm{^oK} \times 1.7 \times 10^{4}\ \mathrm{Hz} = 6.76 \times 10^{-17}\mathrm{W}. \qquad \text{(III-28)}$$

The receiver FM sensitivity is such that a signal generator, with an output impedance z_o = 50 ohms and an open-circuited rms signal voltage v_{oc} = 0.6 μV when placed at the input to the receiver, causes a post-detection audio output with (signal + noise)/noise = 10 dB for ± 5 kHz FM deviation at 1 kHz. The corresponding predetection (signal + noise)/noise ≈ 8 dB as shown in fig. (III-3) for a modulation index m = 5 kHz/1 kHz = 5 for a typical FM receiver[13].

The predetection signal available power p_s corresponding to v_{oc} = 0.6 μV is given by

$$p_s = v_{oc}^2/4z_{so} = (6.0 \times 10^{-7}\ \mathrm{V})^2/(4\mathrm{x}50) = 1.8 \times 10^{-15}\ \mathrm{W} \qquad \text{(III-29)}$$

The predetection noise equivalent power p_n is related to p_s by

$$10 \log_{10}\left(\frac{p_s}{p_n} + 1\right) \approx 8\ \mathrm{dB} \qquad \text{(III-30)}$$

Therefore,

$$p_n = p_s/5.3 = 1.8 \times 10^{-15}\ \mathrm{W}/5.3 = 3.4 \times 10^{-16}\ \mathrm{W} \qquad \text{(III-31)}$$

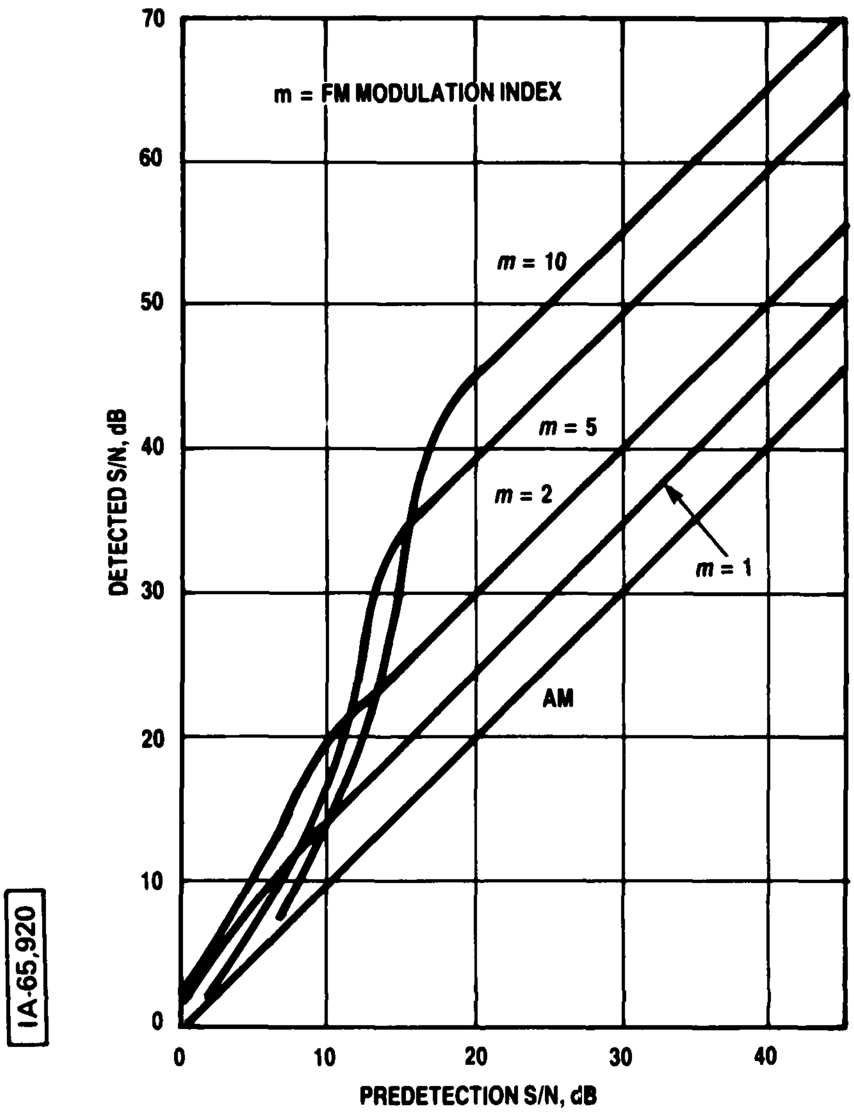

Figure III-3. Detected S/N vs. Predetection S/N. (After C.P. Walsh, "Frequency Modulation Principles", Electro-Technology, January 1965)

Subsituting Eqs. (III-28) and (III-31) into Eq. (III-27),

$$f_o = 3.4 \times 10^{-16}\ W/6.76 \times 10^{-17}\ W = 5.03 \qquad \text{(III-32)}$$

which corresponds to a receiver noise figure $F_o = 10 \log_{10} f_o = 7.0$ dB.

Noise Parameter, r_n

The r_n noise parameter [see Eq. (III-26)] of a Collins VHF-186 receiver (whose AGC was deactivated) and also of a 3N211 MOSFET transistor were measured by MITRE Corporation utilizing a diode noise generator in cascade with a low-loss reactive network with variable output impedance. The measured values were found to be r_n = 45 ohms and 67 ohms, respectively. The first RF stage of the receiver consists of a 3N211 MOSFET preceded by a filter whose insertion loss has the effect of increasing the minimum noise factor of the receiver while decreasing the r_n noise parameter.

The numerical results of Section 3 were obtained by assuming r_n = 100 ohms.

Noise Parameters g_{no}, b_{no}

The receiver is conventionally designed to have a minimum noise factor f_o for a source admittance $y_s = 1/R_e(z_{or}) = 20 \times 10^{-3}$ mhos. Therefore, from Eq. (III-26),

$$\begin{aligned} g_{no} &= 20 \times 10^{-3} \text{ mhos} \\ b_{no} &= 0 \text{ mhos} \end{aligned} \qquad \text{(III-33)}$$

III F Transmission Line Parameters: $Re(z_{or})$, $Im(z_{or})$, α_r, β_r, d_r

The characteristic impedance z_{or} and propagation constant γ_r of a transmission line are given by[14]

$$z_{or} = R_e(z_{or}) + j\, I_m(z_{or}) = [(R + j\omega L)/(G + j\omega C)]^{1/2} \tag{III-34}$$

$$\gamma_r = \alpha_r + j\beta_r = [(R + j\omega L)\ (G + j\omega C)]^{1/2} \tag{III-35}$$

where

R, L = series resistance, inductance per unit length respectively

G, C = shunt conductance, capacitance per unit length repectively

$\omega = 2\pi f$ = radian frequency

RG - 58/U Coaxial Line

RG-58/U is a low-loss line ($R/\omega L \ll 1$, $G/\omega C \ll 1$) with a copper conductor and polyethylene dielectric of dielectric constant $\varepsilon_r = 2.3$, dielectric loss factor $F_p = 5 \times 10^{-4}$, and relative permeability $\mu_r = 1$.

For RG-58/U coaxial line, Eqs.(III-34) and (III-35) reduce to[14]

$$Re(z_{or}) \approx (L/C)^{1/2} = 50 \text{ ohms} \tag{III-36}$$

$$\beta_r \approx \omega(LC)^{1/2} = \frac{2\pi f}{c} \quad (\epsilon_r \mu_r)^{1/2} = 3.18 \times 10^{-2}\ f_{MHz} \text{ nepers/m} \tag{III-37}$$

where

$$c = (\epsilon_o \mu_o)^{1/2} = \text{wave velocity in free space} \approx 3 \times 10^8 \text{ m/s}$$

$$\alpha_r \approx \frac{1}{2}\ [R(C/L)^{1/2} + G(L/C)^{1/2} = \beta_r[\frac{1}{2}\ (\ \frac{R}{\omega L} + \frac{G}{\omega C})] = \alpha_c + \alpha_d$$

$$= 1.68 \times 10^{-3}\ (f_{MHz})^{1/2} + 8.0 \times 10^{-6}\ f_{MHz} \text{ nepers/m} \tag{III-38}$$

where

$$\alpha_c = \text{conductor attenuation constant} \approx \frac{1}{2}\ R(C/L)^{1/2}$$

$$= 1.68 \times 10^{-3}\ (f_{MHz})^{1/2} \text{ nepers/m}$$

$$\alpha_d = \text{dielectric attenuation constant} \approx \frac{1}{2}\ G\ (L/C)^{1/2}$$

$$= 1.05 \times 10^{-2}\ f_{MHz}\ F_p(\epsilon_r)^{1/2} = 8.0 \times 10^{-6}\ f_{MHz} \text{ nepers/m}$$

$$Im(z_{or})/Re(z_{or}) \approx \frac{1}{2}\ (\ \frac{G}{\omega C} - \frac{R}{\omega L}) = (\alpha_d - \alpha_c)/\beta_r$$

$$= \frac{8.0 \times 10^{-6}\ f_{MHz} - 1.68 \times 10^{-3}\ (f_{MHz})^{1/2}}{3.18 \times 10^{-2}\ f_{MHz}}$$

$$= 2.5 \times 10^{-4} - 5.3 \times 10^{-2}\ (f_{MHz})^{-1/2} \tag{III-39}$$

$$Im(z_{or}) = 1.25 \times 10^{-2} - 2.65\ (f_{MHz})^{-1/2} \text{ ohms} \tag{III-40}$$

The nominal length d_r of the transmission line for installation of the receiver system in many aircrafts of interest are

$$d_r = 10 \text{ m} \tag{III-41}$$

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 2

SCENARIO MATCHING NETWORK
RESIDENTIAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ)
2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K)
4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS)
7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 2799E+01 (OHMS)
10 XMR= 0 1000E+04 (OHMS)
11 A 0 3889E+01 (------)
12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (------)
14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)
16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)
18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)
20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 3158E+02 (dB)
23 DUFAT= 0 1121E+02 (dB)
24 DLFAT= 0 6710E+01 (dB)
25 FALSTD= 0 4410E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K)
2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)
2 ZOUT= (0 5000E+02 , 0 0000E+00) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (- 2218E-04 , 0 4713E-02) (------)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1996E-01 , 0 3633E-04) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS)
8 FR= 0 5030E+01 (------)

9 FATSTD= 0 7080E+01 (dB)
10 FASTD= 0 8341E+01 (dB)

11 SFAMEAN= 0 9106E+04 (------)
12 SFASTD= 0 5686E+05 (------)

13 LCR= 0 1004E+01 (------)
14 LMR= 0 1288E+02 (------)

15 LNR= 0 1208E+01 (------)

16 SFMEAN= 0 9184E+04 (------)

17 SFSTD= 0 5686E+05 (------)
18 FSTD= 0 8322E+01 (dB)

19 FMEAN= 0 3166E+02 (dB)
20 DFMEAN= 0 7276E-01 (dB)

21 SDFMEAN= 0 1009E+01 (------)
22 NMEAN= - 1000E+03 (dBm)

23 NSTD= 0 8322E+01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 1
SCENARIO MATCHING NETWORK
BUSINESS AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 2799E+01 (OHMS) 10 XMR= 0 1000E+04 (OHMS)
11 A= 0 3889E+01 (-----) 12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 3588E+02 (dB) 23 DUFAT= 0 1143E+02 (dB)
24 DLFAT= 0 7779E+01 (dB) 25 FALSTD= 0 5720E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 5000E+02 , 0 0000E+00) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (- 2218E-04 , 0 4713E-02) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1996E-01 , 0 3633E-04) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 5030E+01 (-----)

9 FATSTD= 0 7553E+01 (dB) 10 FASTD= 0 9474E+01 (dB)

11 SFAMEAN= 0 4186E+05 (-----) 12 SFASTD= 0 4501E+06 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1288E+02 (-----)

15 LNR= 0 1208E+01 (-----)

16 SFMEAN= 0 4194E+05 (-----)

17 SFSTD= 0 4501E+06 (-----) 18 FSTD= 0 9471E+01 (dB)

19 FMEAN= 0 3590E+02 (dB) 20 DFMEAN= 0 1602E-01 (dB)

21 SDFMEAN= 0 1002E+01 (-----) 22 NMEAN= - 9580E+02 (dBm)

23 NSTD= 0 9471E+01 (dB)

IV A. Receiving System with a Matching Network

TRANSMISSION LINE LENGTH = 10 m

Run 1	Business Area	30 MHz
Run 2	Residential Area	30 MHz
Run 3	Rural Area	30 MHz
Run 4	Business Area	50 MHz
Run 5	Residential Area	50 MHz
Run 6	Rural Area	50 MHz
Run 7	Business Area	88 MHz
Run 8	Residential Area	88 MHz
Run 9	Rural Area	88 MHz

APPENDIX IV

PROGRAM SONF PRINTOUTS: VHF-FM RECEIVING SYSTEM WITH AN ELECTRICALLY-SHORT MONOPOLE ANTENNA

CONTENTS

References, Appendix III (concluded)

15. A. D. Spaulding and R. T. Disney, "Man-Made Radio Noise, Part 1: Estimates for Business, Residential, and Rural Areas", OT Report 74-38, Dept. of Commerce, Boulder, CO., June 1974. Available from the U. S. Government Printing Office, Washington, D.C.

16. C. C. I. R. "Man-Made Radio Noise", Report 258-3, Int. Radio Consultative Committee, Int. Telecommunication Union, Geneva, Switzerland 1980.

17. G. H. Hagn, "VHF Radio System Performance Model for Predicting Communications Operational Ranges in Irregular Terrain", IEEE Transactions on Communications, Vol. COM-28, No. 9, pp. 1637-1644, September, 1980.

4. E. A. Wolff, "Antenna Analysis" (John Wiley & Sons, NY, 1966), p. 47, Eq. (3.174). In Eq. (3.174) of Ref. [4], the reactance is for a dipole with respect to the loop current I_m. For a monopole. one-half the value given by Eq. (3.174) should be utilized. Applying conditions (III-1), dividing by 2, and expressing the reactance with respect to the base current I(0), Eq. (3.174) reduces to the value of $x_{a,r}$ found from Ref. [3]. It should be noted that

$$-\mathrm{Ci}(\beta a_o^2/h) \approx -\gamma + \ln(h/\beta a_o^2) \text{ for } (h/\beta a_o^2) << 1.$$

5. R. W. P. King, "The Theory of Linear Antennas" (Harvard University Press, Cambridge, MA, 1956). p. 184, Eq. (6c). In Eq. (6c) of Ref [5], the reactance X_o is for a dipole in free space with respect to the base current I(0). The reactance $x_{a,r}$ is related to X_o by

$$x_{a,r} = (X_o/2)\ (\mu_r/\epsilon_r)^{1/2} = -\ (\mu_r/\epsilon_r)^{1/2}\ \frac{30}{\beta h}\ [2\ \ln\left(\frac{2h}{a_o}\right) - 2\ -2\ \ln 2]$$

$$= -\left(\frac{\mu_r}{\epsilon_r}\right)^{1/2} \frac{60}{\beta h}\left[\ln\left(\frac{h}{a_o}\right) - 1\right]$$

6. R. B. Adler, L. J. Chu, and R. M. Fano, "Electromagnetic Energy Transmission and Radiation" (John Wiley & Sons, NY, 1960), p. 588, Eq. (10.69).

7. S. Ramo and J. R. Whinnery, "Fields and Waves in Modern Radio" (John Wiley & Sons, N.Y. 1953), p. 245, Eq. (1).

8. op. cit. 2, p. 563, Eq. (14-50)

9. ITT, "Reference Data for Radio Engineers (Howard W. Sams and Co., Indianopolis, 5th edition, 1970) Chapter 6, pp. 6-1 to 6-4.

10. F. Terman, "Radio Engineers Handbook" (McGraw - Hill, N.Y., 1943), p. 77-79.

11. H. A. Haus, et al, "IRE Standards on Methods of Measuring Noise in Linear Two-Ports, 1959", Proc. of the IRE, Vol. 48, pp. 61-68, January 1960.

12. H. A. Haus, et al, "Representation of Noise in Linear Two-Ports", Proc. of the IRE, Vol. 48, p. 61-68, January 1960.

13. C. P. Walsh, "Frequency Modulation Principles" Electro-Technology, January 1965.

14. op. cit. 9, Chapter 22.

References (Appendix III)

1. C. C. I. R., "Man-Made Noise", 14th Plenary Assembly, Kyoto, Japan (1978), Report 258-3, Int. Radio Consultative Committee, Int. Telecommun. Union, Geneva, Switzerland, 1980. The temperature 288 deg K is conveniently chosen as a reference temperature because $10 \log_{10}(kt_{ref}) = 10 \log_{10} (1.38044 \times 10^{-23}$ J/deg K x 288 deg K) = -204.0059 dBj is approximately a whole number.

2. E. C. Jordan and K. G. Balman, "Electromagnetic Waves and Radiating Systems" (Prentice-Hall, Englewood Cliffs, NJ, 1968) p. 326. In Ref.[2], $\mu_r = \epsilon_r = 1$.

3. op. cit. 2, p. 547, Eq. (14-24). In Eq. (14-24) of Ref. [3], the reactance X is with respect to the loop current I_m instead of the base current I(0). The reactance $x_{a,r}$ is related to X by

$$x_{a,r} = X\,(\mu_r/\epsilon_r)^{1/2} \sin^{-2}(\beta h)$$

$$= -\left(\frac{\mu_r}{\epsilon_r}\right)^{1/2} \frac{15}{\sin^2(\beta h)} \left\{ \sin(2\beta h)\left[-2\,\mathrm{Ci}\left(\frac{\beta a_o^2}{2h}\right) + \mathrm{Ci}\left(\frac{\beta a_o^2}{4h^2}\right) + 2\,\mathrm{Ci}(2\beta h) - \mathrm{Ci}(4\beta h)\right] - \cos(2\beta h)\left[2\mathrm{Si}(2\beta h) - \mathrm{Si}(4\beta h)\right] - 2\,\mathrm{Si}(2\beta h) \right\}$$

$$\approx -\left(\frac{\mu_r}{\epsilon_r}\right)^{1/2} \left\{ \frac{15}{(\beta h)^2} (2\beta h)\left[-\gamma + \ln\left(\frac{h}{\beta a_o^2}\right) + 2\gamma + 2\ln(2\beta h) - \gamma - \ln(4\beta h)\right] - [2(2\beta h) - 4\beta h] - 2(2\beta h) \right\}$$

$$= -\left(\frac{\mu_r}{\epsilon_r}\right)^{1/2} \left[\frac{60}{\beta h} \ln\left(\frac{h}{a_o}\right) + 1\right] \quad \text{, conditions (III-1).}$$

Table III-4. Representative Values, $D_{u,F_{a,t}}$ and $D_{\ell,F_{a,t}}$, of Upper and Lower Deciles, Respectively, Relative to the Median, of Noise Power Time Variability within the Hour at a Given Location.

CLASSIFICATION AREA	$D_{u,F_{a,t}}$ (dB)		$D_{\ell,F_{a,t}}$ (dB)	
	$20 \le f_{MHz} \le 48$ MHz	$48 \le f_{MHz} \le 102$ MHz	$20 \le f_{MHz} \le 48$ MHz	$48 \le f_{MHz} \le 102$ MHz
BUSINESS	$10.5 + 0.093\ (f_{MHz}-20)$	$13.1 - 0.022\ (f_{MHz}-48)$	$7.6 + 0.0179\ (f_{MHz}-20)$	$8.1 - 0.44\ (f_{MHz}-48)$
RESIDENTIAL	$10.6 + 0.061\ (f_{MHz}-20)$	$12.3 + 0.0037\ (f_{MHz}-48)$	$6.5 + 0.021\ (f_{MHz}-20)$	$7.1 - 0.042\ (f_{MHz}-48)$
RURAL	$7.8 - 0.089\ (f_{MHz}-20)$	$5.3 +0.096\ (f_{MHz}-48)$	$5.5 -0.132\ (f_{MHz}-20)$	$1.8 + 0.024\ (f_{MHz}-48)$

Table III-3. Expected Variation, Man-Made Radio Noise Levels, about the Median Value for a Location, within the Hour. (after Spaulding and Disney, 1974)

Frequency MHz	Business Area $D_{u,F_{a,t}}$ (dB)	Business Area $D_{\ell,F_{a,t}}$ (dB)	Residential Area $D_{u,F_{a,t}}$ (dB)	Residential Area $D_{\ell,F_{a,t}}$ (dB)	Rural Area $D_{u,F_{a,t}}$ (dB)	Rural Area $D_{\ell,F_{a,t}}$
0.25	8.1	6.1	9.3	5.0	10.6	2.8
0.5	12.6	8.0	12.3	4.9	12.5	4.0
1.0	9.8	4.0	10.0	4.4	9.2	6.6
2.5	11.9	9.5	10.1	6.2	10.1	5.1
5	11.0	6.2	10.0	5.7	5.9	7.5
10	10.9	4.2	8.4	5.0	9.0	4.0
20	10.5	7.6	10.6	6.5	7.8	5.5
48	13.1	8.1	12.3	7.1	5.3	1.8
102	11.9	5.7	12.5	4.8	10.5	3.1
250	6.7	3.2	6.9	1.8	3.5	0.8

TABLE III-2

STANDARD DEVIATION $\sigma_{F_{a,\ell}}$ OF NOISE POWER LOCATION VARIABILITY OF HOURLY MEDIAN VALUES WITHIN SIMILAR CLASSIFICATION AREAS.

CLASSIFICATION AREA	$\sigma_{F_{a,\ell}}$ (dB)	
	$20 \le f_{MHz} \le 48$ MHz	$48 \le f_{MHz} \le 102$ MHz
BUSINESS	$4.93 + 0.079\ (f_{MHz} - 20)$	$7.13 + 0.030\ (f_{MHz} - 48)$
RESIDENTIAL	$4.65 - 0.024\ (f_{MHz} - 20)$	$3.98 - 0.023\ (f_{MHz} - 48)$
RURAL	$4.53 - 0.046\ (f_{MHz} - 20)$	$3.23 - 0.0109\ (f_{MHz} - 48)$

Table III-1. Expected Variation of Median Values about Estimates for Business, Residential, and Rural Locations. (after Spaulding and Disney, 1974)

Frequency in MHz	Standard Deviation, $\sigma_{F_{a,\ell}}$ (dB)		
	Business	Residential	Rural
0.25	6.12	3.54	3.89
0.5	8.21	4.28	4.40
1.0	2.33	2.52	7.13
2.5	9.14	8.06	8.02
5.0	6.08	5.54	7.74
10.0	4.15	2.91	4.03
20.0	4.93	4.65	4.53
48.0	7.13	3.98	3.23
102.0	8.76	2.73	3.82
250.0	3.77	2.87	2.26

$\underline{\sigma_{F_{a,\ell}}}$

The standard deviation $\sigma_{F_{a,\ell}}$ (in dB), of location variability of antenna external noise figure, is given in table III-1 for business, residential, and rural areas. Table III-2 is a linear interpolation of the values for $\sigma_{F_{a,\ell}}$ given in Table III-1.

$\underline{D_{\mu,F_{a,t}},\ D_{\ell,F_{a,t}}}$

The upper and lower deciles relative to median values, of time variability of antenna external noise figure, are given in table III-3 for business, residential, and rural areas. Table III-4 is a linear interpolation of the values for $D_{\mu,F_{a,t}}$ and $D_{\ell,F_{a,t}}$ at 20, 48, and 102 MHz given in table III-3.

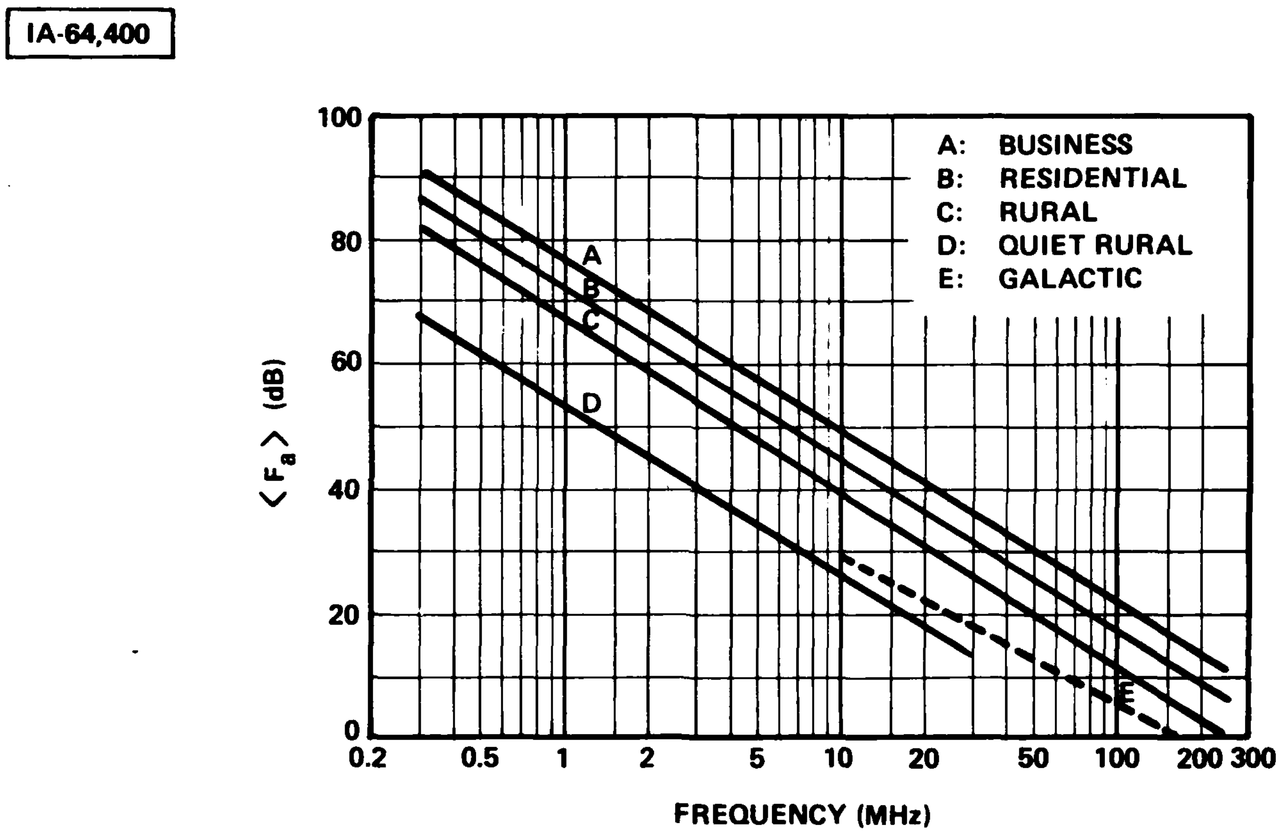

Figure III-4. Expected Values of Man-Made Noise (After C.C.I.R., Report 258-3, 1980)

III G. Man-Made Environmental Noise Parameters:

$$\langle F_a \rangle,\ D_{\mu, F_{a,t}},\ D_{\ell, F_{a,t}},\ \sigma_{F_{a,\ell}}$$

$\langle F_a \rangle$

The expected value $\langle F_a \rangle$ (in dB) of the antenna external noise figure for rural, residential, and business areas is plotted in fig. III-4. These values are with respect to thermal noise at a temperature $t_{ref} = 288^{\circ}K$ and are for an electrically short vertical lossless grounded monopole receiver antenna. The corresponding expressions are given by [15],[16],[17]

$$\langle F_a \rangle = \begin{cases} -27.7 \log_{10} f_{MHz} + 67.2, & \text{rural areas} \\ -27.7 \log_{10} f_{MHz} + 72.5, & \text{residential areas} \\ -27.7 \log_{10} f_{MHz} + 76.8, & \text{business areas} \end{cases} \qquad \text{(III-42)}$$

where

f_{MHz} = frequency in MHz.

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 3
SCENARIO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ) 2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K) 4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS) 7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.2799E+01 (OHMS) 10 XMR= 0.1000E+04 (OHMS)
11 A= 0.3889E+01 (-----) 12 RSR= 0.2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----) 14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS) 16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS) 18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER) 20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB) 23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB) 25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K) 2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm) 2 ZOUT= (0.5000E+02 , 0.0000E+00) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (-.2218E-04 , 0.4713E-02) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.1996E-01 , 0.3633E-04) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS) 8 FR= 0.5030E+01 (-----)

9 FATSTD= 0.4379E+01 (dB) 10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----) 12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----) 14 LMR= 0.1288E+02 (-----)

15 LNR= 0.1208E+01 (-----)

16 SFMEAN= 0.1174E+04 (-----)

17 SFSTD= 0.2606E+04 (-----) 18 FSTD= 0.5794E+01 (dB)

19 FMEAN= 0.2683E+02 (dB) 20 DFMEAN= 0.5466E+00 (dB)

21 SDFMEAN= 0.1071E+01 (-----) 22 NMEAN= -.1049E+03 (dBm)

NSTD= 0.5794E+01 (dB)

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                Run 4
SCENARIO  MATCHING NETWORK
          BUSINESS AREA
          FREQUENCY, 50MHz
          10" MONOPOLE ANTENNA, 1.4 in  DIA
          RECEIVER    fo =5,  rn =100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                        INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 5000E+02 (MHZ)                 2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                 4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1371E-02 (OHMS)                 7  RAR= 0 7100E+00 (OHMS)
8  XAR= - 6000E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 1301E+01 (OHMS)                10 XMR= 0 6000E+03 (OHMS)
11 A= 0 4701E+01 (-----)                  12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)               18 IMZOR= - 3623E+00 (OHMS)
19 ALPHAR= 0 1228E-01 (NEPERS/METER)      20 BETAR= 0 1590E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2974E+02 (dB)                23 DUFAT= 0 1306E+02 (dB)
24 DLFAT= 0 7220E+01 (dB)                 25 FALSTD= 0 7190E+01 (dB)

                        CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                 2  K= 0 1380E-22 (J/DEG K)

                        DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                 2  ZOUT= (0 5000E+02 , 0 0000E+00) (OHMS)

3  ZOR= (0 5000E+02 , - 3623E+00) (OHMS)

4  REFLR= (- 1312E-04 , 0 3623E-02) (-----)

5  GAMMAR= (0 1228E-01 , 0 1590E+01) (NEPERS/METER)

6  YS= (0 1996E-01 , 0 3957E-04) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 5030E+01 (-----)

9  FATSTD= 0 8039E+01 (dB)             10 FASTD= 0 1078E+02 (dB)

11 SFAMEAN= 0 2056E+05 (-----)         12 SFASTD= 0 4484E+06 (-----)

13 LCR= 0 1002E+01 (-----)             14 LMR= 0 3180E+01 (-----)

15 LNR= 0 1278E+01 (-----)

16 SFMEAN= 0 2058E+05 (-----)

17 SFSTD= 0 4484E+06 (-----)           18 FSTD= 0 1078E+02 (dB)

19 FMEAN= 0 2975E+02 (dB)              20 DFMEAN= 0 8228E-02 (dB)

21 SDFMEAN= 0 1001E+01 (-----)         22 NMEAN= - 1020E+03 (dBm)

23 NSTD= 0 1078E+02 (dB)
```

```
PROGRAM SONF   SYSTEM OPERATING NOISE FIGURE                    Run 5
SCENARIO   MATCHING NETWORK
           RESIDENTIAL AREA
           FREQUENCY, 50MHz
           10" MONOPOLE ANTENNA, 1.4 in. DIA.
           RECEIVER    fo=5, rn=100 OHMS
           RG-58/U COAXIAL LINE, 10M LENGTH

                        INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0.5000E+02 (MHZ)                2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)                4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1371E-02 (OHMS)                7  RAR= 0.7100E+00 (OHMS)
8  XAR= -.6000E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0.1301E+01 (OHMS)               10 XMR= 0.6000E+03 (OHMS)
11 A= 0.4701E+01 (-----)                 12 RSR= 0.2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)                14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)                16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)              18 IMZOR= -.3623E+00 (OHMS)
19 ALPHAR= 0.1228E-01 (NEPERS/METER)     20 BETAR= 0.1590E+01 (NEPERS/METER)
21 DR= 0.1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2544E+02 (dB)               23 DUFAT= 0.1231E+02 (dB)
24 DLFAT= 0.7016E+01 (dB)                25 FALSTD= 0.3934E+01 (dB)

                        CONSTANTS, TABLE 2

1  TO= 0.2880E+03 (DEG K)                2  K= 0.1380E-22 (J/DEG K)

                        DERIVED  VARIABLES, TABLE 3

1  W= -.1317E+03 (dBm)                2  ZOUT= (0.5000E+02 , 0.0000E+00) (OHMS)

3  ZOR= (0.5000E+02 , -.3623E+00) (OHMS)

4  REFLR= (-.1312E-04 , 0.3623E-02) (-----)

5  GAMMAR= (0.1228E-01 , 0.1590E+01) (NEPERS/METER)

6  YS= (0.1996E-01 , 0.3957E-04) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8  FR= 0.5030E+01 (-----)

9  FATSTD= 0.7650E+01 (dB)             10 FASTD= 0.8603E+01 (dB)

11 SFAMEAN= 0.2488E+04 (-----)         12 SFASTD= 0.1752E+05 (-----)

13 LCR= 0.1002E+01 (-----)             14 LMR= 0.3180E+01 (-----)

15 LNR= 0.1278E+01 (-----)

16 SFMEAN= 0.2507E+04 (-----)

17 SFSTD= 0.1752E+05 (-----)           18 FSTD= 0.8586E+01 (dB)

19 FMEAN= 0.2551E+02 (dB)              20 DFMEAN= 0.6710E-01 (dB)

21 SDFMEAN= 0.1008E+01 (-----)         22 NMEAN= -.1062E+03 (dBm)

23 NSTD= 0.8586E+01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 6
SCENARIO  MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 50MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                    INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 5000E+02 (MHZ)                2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1371E-02 (OHMS)                7  RAR= 0 7100E+00 (OHMS)
8  XAR= - 6000E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 1301E+01 (OHMS)               10 XMR= 0 6000E+03 (OHMS)
11 A= 0 4701E+01 (-----)                 12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)              18 IMZOR= - 3623E+00 (OHMS)
19 ALPHAR= 0 1228E-01 (NEPERS/METER)     20 BETAR= 0 1590E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2014E+02 (dB)               23 DUFAT= 0 5492E+01 (dB)
24 DLFAT= 0 1848E+01 (dB)                25 FALSTD= 0 3208E+01 (dB)

                    CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                2  K= 0 1380E-22 (J/DEG K)

                    DERIVED  VARIABLES, TABLE 3

1  W= - 1217E+03 (dBm)              2  ZOUT= (0 5000E+02 , 0 0000E+00) (OHMS)

3  ZOR= (0 5000E+02 , - 3623E+00) (OHMS)

4  REFLR= (- 1312E-04 , 0 3623E-02) (-----)

5  GAMMAR= (0 1228E-01 , 0 1590E+01) (NEPERS/METER)

6  YS= (0 1996E-01 , 0 3957E-04) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 5030E+01 (-----)

9  FATSTD= 0 2993E+01 (dB)          10 FASTD= 0 4387E+01 (dB)

11 SFAMEAN= 0 1720E+03 (-----)      12 SFASTD= 0 2291E+03 (-----)

13 LCR= 0 1002E+01 (-----)          14 LMR= 0 3180E+01 (-----)

15 LNR= 0 1278E+01 (-----)

16 SFMEAN= 0 1915E+03 (-----)

17 SFSTD= 0 2291E+03 (-----)        18 FSTD= 0 4094E+01 (dB)

19 FMEAN= 0 2089E+02 (dB)           20 DFMEAN= 0 7527E+00 (dB)

21 SDFMEAN= 0 1113E+01 (-----)      22 NMEAN= - 1108E+03 (dBm)

23 NSTD= 0 4094E+01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 7
SCENARIO MATCHING NETWORK
BUSINESS AREA
FREQUENCY, 88MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 8800E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN 0 2880E+03 (DEG K)

ANTENNA
6 RLR= 0 1819E-02 (OHMS) 7 RAR= 0 2199E+01 (OHMS)
8 XAR= - 3409E+03 (OHMS)

MATCHING NETWORK
9 RMR= 0 5572E+00 (OHMS) 10 XMR= 0 3409E+03 (OHMS)
11 A= 0 4077E+01 (-----) 12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 2700E+00 (OHMS)
19 ALPHAR= 0 1646E-01 (NEPERS/METER) 20 BETAR= 0 2798E+01 (NEPERS/METER)
21 DR 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2294E+02 (dB) 23 DUFAT= 0 1222E+02 (dB)
24 DLFAT= - 9500E+01 (dB) 25 FALSTD= 0 8330E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 5000E+02 , 0 0000E+00) (OHMS)

3 ZOR= (0 5000E+02 , - 2700E+00) (OHMS)

4 REFLR= (- 7251E-05 , 0 2700E-02) (-----)

5 GAMMAR= (0 1646E-01 , 0 2798E+01) (NEPERS/METER)

6 YS= (0 2004E-01 , 0 4324E-04) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 5030E+01 (-----)

9 FATSTD= 0 5222E+01 (dB) 10 FASTD= 0 9832E+01 (dB)

11 SFAMEAN= 0 2551E+04 (-----) 12 SFASTD= 0 3298E+05 (-----)

13 LCR= 0 1001E+01 (-----) 14 LMR= 0 1367E+01 (-----)

15 LNR= 0 1390E+01 (-----)

16 SFMEAN= 0 2559E+04 (-----)

17 SFSTD= 0 3298E+05 (-----) 18 FSTD= 0 9825E+01 (dB)

FMEAN= 0 2297E+02 (dB) 20 DFMEAN= 0 2903E-01 (dB)

21 SDFMEAN= 0 1003E+01 (-----) 22 NMEAN= - 1087E+03 (dBm)

23 NSTD= 0 9825E+01 (dB)

```
PROGRAM SONF   SYSTEM OPERATING NOISE FIGURE                    Run 8
SCENARIO  MATCHING NETWORK
          RESIDENTIAL AREA
          FREQUENCY, 88MHz
          10" MONOPOLE ANTENNA, 1.4 in. DIA
          RECEIVER   fo =5, rn =100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                        INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0.8800E+02 (MHZ)                 2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)                 4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1819E-02 (OHMS)                 7  RAR= 0.2199E+01 (OHMS)
8  XAR= -.3409E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0.5572E+00 (OHMS)                10 XMR= 0.3409E+03 (OHMS)
11 A= 0.4077E+01 (-----)                  12 RSR= 0.2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)                 14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)                 16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)               18 IMZOR= -.2700E+00 (OHMS)
19 ALPHAR= 0.1646E-01 (NEPERS/METER)      20 BETAR= 0.2798E+01 (NEPERS/METER)
21 DR= 0.1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.1864E+02 (dB)                23 DUFAT= 0.1245E+02 (dB)
24 DLFAT= 0.5420E+01 (dB)                 25 FALSTD= 0.3060E+01 (dB)

                        CONSTANTS, TABLE 2

1  TO= 0.2880E+03 (DEG K)                 2  K= 0.1380E-22 (J/DEG K)

                        DERIVED  VARIABLES, TABLE 3

1  W= -.1317E+03 (dBm)                    2  ZOUT= (0.5000E+02 , 0.0000E+00) (OHMS)

3  ZOR= (0.5000E+02 , -.2700E+00) (OHMS)

4  REFLR= (-.7251E-05 , 0.2700E-02) (-----)

5  GAMMAR= (0.1646E-01 , 0.2798E+01) (NEPERS/METER)

6  YS= (0.2004E-01 , 0.4324E-04) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)  8  FR= 0.5030E+01 (-----)

9  FATSTD= 0.7173E+01 (dB)                10 FASTD= 0.7799E+01 (dB)

11 SFAMEAN= 0.3664E+03 (-----)            12 SFASTD= 0.1800E+04 (-----)

13 LCR= 0.1001E+01 (-----)                14 LMR= 0.1367E+01 (-----)

15 LNR= 0.1390E+01 (-----)

16 SFMEAN= 0.3750E+03 (-----)

17 SFSTD= 0.1800E+04 (-----)              18 FSTD= 0.7745E+01 (dB)

19 FMEAN= 0.1883E+02 (dB)                 20 DFMEAN= 0.1966E+00 (dB)

21 SDFMEAN= 0.1023E+01 (-----)            22 NMEAN= -.1129E+03 (dBm)

23 NSTD= 0.7745E+01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 9
SCENARIO  MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 88MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                          INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 8800E+02 (MHZ)                  2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                  4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1819E-02 (OHMS)                  7  RAR= 0 2199E+01 (OHMS)
8  XAR= - 3409E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 5572E+00 (OHMS)                 10 XMR= 0 3409E+03 (OHMS)
11 A= 0 4077E+01 (-----)                   12 RSR= 0 2500E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                  14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                  16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)                18 IMZOR=   2700E+00 (OHMS)
19 ALPHAR= 0 1646E-01 (NEPERS/METER)       20 BETAR= 0 2798E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 1334E+02 (dB)                 23 DUFAT= 0 9140E+01 (dB)
24 DLFAT= 0 2760E+01 (dB)                  25 FALSTD= 0 2794E+01 (dB)

                            CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                  2  K= 0 1380E-22 (J/DEG K)


                        DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                 2  ZOUT= (0 5000E+02   0 0000E+00) (OHMS

3  ZOR= (0 5000E+02 , - 2700E+00) (OHMS)

4  REFLR= (- 7251E-05 , 0 2700E-02) (------)

5  GAMMAR= (0 1646E-01 , 0 2798E+01) (NEPERS/METER)

6  YS= (0 2004E-01 , 0 4324E-04) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 5030E+01 (

9  FATSTD= 0 4885E+01 (dB)             10 FASTD= 0 5628E+01 (dB)

11 SFAMEAN= 0 4993E+02 (-----)         12 SFASTD= 0 1043E+03 (

13 LCR= 0 1001E+01 (-----)             14 LMR= 0 1367E+01 (

15 LNR= 0 1390E+01 (-----)

16 SFMEAN= 0 5850E+02 (-----)

17 SFSTD= 0 1043E+03 (-----)           18 FSTD= 0 5193E+01 (dB)

19 FMEAN= 0 1457E+02 (dB)              20 DFMEAN= 0 1229E+01 (dB)

21 SDFMEAN= 0 1171E+01 (-----)         22 NMEAN= - 1171E+03 (dBm)

23 NSTD= 0 5193E+01 (dB)
```

IV B. Receiving System without a Matching Network

TRANSMISSION LINE LENGTH = 10 m

Run 10	Business Area	30 MHz
Run 11	Residential Area	30 MHz
Run 12	Rural Area	30 MHz
Run 13	Business Area	50 MHz
Run 14	Residential Area	50 MHz
Run 15	Rural Area	50 MHz
Run 16	Business Area	88 MHz
Run 17	Residential Area	88 MHz
Run 18	Rural Area	88 MHz

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 10

SCENARIO NO MATCHING NETWORK
BUSINESS AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 3588E+02 (dB) 23 DUFAT= 0 1143E+02 (dB)
24 DLFAT= 0 7779E+01 (dB) 25 FALSTD= 0 5720E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1913E-02 , 0. 3321E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 2271E+0[illegible] (-----)

9 FATSTD= 0. 7553E+01 (dB) 10 FASTD= 0 9474E+01 (dB)

11 SFAMEAN= 0. 4186E+05 (-----) 12 SFASTD= 0 4501E+06 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 7348E+04 (-----)

16 SFMEAN= 0. 2094E+06 (-----)

17 SFSTD= 0 4501E+06 (-----) 18 FSTD= 0 5706E+01 (dB)

19 FMEAN= 0 4946E+02 (dB) 20 DFMEAN= 0 1358E+02 (dB)

21 SDFMEAN= 0. 5003E+01 (-----) 22 NMEAN= - 8224E+02 (dBm)

23 NSTD= 0. 5706E+01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE   Run 11

SCENARIO NO MATCHING NETWORK

RESIDENTIAL AREA

FREQUENCY, 30MHz

10" MONOPOLE ANTENNA, 1 4 in DIA

RECEIVER f_o=5, r_n=100 OHMS

RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY

1 FMHZ= 0 3000E+02 (MHZ)   2 B= 0 1700E+05 (HZ)

TEMPERATURE

3 TC= 0 2880E+03 (DEG K)   4 TM 0 2880E+03 (DEG K)

5 TN= 0 2880E+03 (DEG K)

ANTENNA

6 RCR= 0 1062E-02 (OHMS)   7 RAR= 0 2556E+00 (OHMS)

8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK

9 RMR= 0 0000E+00 (OHMS)   10 XMR= 0 0000E+00 (OHMS)

11 A 0 1000E+01 (-----)   12 RSR 0 0000E+00 (OHMS)

RECEIVER NOISE

13 FO= 0 5030E+01 (-----)   14 RN= 0 1000E+03 (OHMS)

15 GNO= 0 2000E-01 (MHOS)   16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE

17 REZOR= 0 5000E+02 (OHMS)   18 IMZOR= - 4713E+00 (OHMS)

19 ALPHAR= 0 9442E-02 (NEPERS/METER)   20 BETAR= 0 9540E+00 (NEPERS/METER)

21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE

22 FAMEAN= 0 3158E+02 (dB)   23 DUFAT= 0 1121E+02 (dB)

24 DLFAT= 0 6710E+01 (dB)   25 FALSTD= 0 4410E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K)   2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)   2 ZOUT= (0 2567E+00 , 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1913E-02 , 0.3321E-02) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8 FR= 0 2271E+02 (-----)

9 FATSTD= 0 7080E+01 (dB)   10 FASTD 0 8341E+01 (dB)

11 SFAMEAN= 0 9106E+04 (-----)   12 SFASTD 0 5686E+05 (-----)

13 LCR= 0 1004E+01 (-----)   14 LMR= 0 1000E+01 (-----)

15 LNR= 0 7348E+04 (-----)

16 SFMEAN= 0 1766E+06 (-----)

17 SFSTD= 0 5686E+05 (-----)   18 FSTD= 0 1364E+01 (dB)

19 FMEAN= 0 5226E+02 (dB)   20 DFMEAN= 0 2067E+02 (dB)

21 SDFMEAN= 0 1940E+02 (-----)   22 NMEAN= - 7945E+02 (dBm)

23 NSTD= 0 1364E+01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 12
SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ)   2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K)   4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS)   7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS)   10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)   12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)   14 RN= 0 1000E+02 (OHMS)
15 GNO= 0 2000E-01 (MHOS)   16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)   18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)   20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)   23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)   25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K)   2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)   2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1913E-02 , 0 3321E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS)   8 FR= 0 2271E+0 (-----)

9 FATSTD= 0 4379E+01 (dB)   10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----)   12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----)   14 LMR= 0 1000E+01 (-----)

15 LNR= 0 7348E+04 (-----)

16 SFMEAN= 0 1686E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)   18 FSTD= 0 6712E-01 (dB)

19 FMEAN= 0 5227E+02 (dB)   20 DFMEAN= 0 2599E+02 (dB)

21 SDFMEAN= 0 1538E+03 (-----)   22 NMEAN= - 7943E+02 (dBm)

23 NSTD= 0 6712E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE — Run 13

SCENARIO NO MATCHING NETWORK
BUSINESS AREA
FREQUENCY, 50MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

```
                    INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 5000E+02 (MHZ)                2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1371E-02 (OHMS)                7  RAR= 0 7100E+00 (OHMS)
8  XAR= - 6000E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)              10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)               14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)               16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)             18 IMZOR= - 3623E+00 (OHMS)
19 ALPHAR= 0 1228E-01 (NEPERS/METER)    20 BETAR= 0 1590E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2974E+02 (dB)              23 DUFAT= 0 1306E+02 (dB)
24 DLFAT= 0 7220E+01 (dB)               25 FALSTD= 0 7190E+01 (dB)

                     CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)               2  K= 0 1380E-22 (J/DEG K)

                  DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                2  ZOUT= (0 7114E+00 ,  - 6000E+03) (OHMS)

3  ZOR= (0 5000E+02 , - 3623E+00) (OHMS)

4  REFLR= (0 9848E+00 , - 1653E+00) (-----)

5  GAMMAR= (0 1228E-01 , 0 1590E+01) (NEPERS/METER)

6  YS= (0 2610E-02 , 0 5574E-02) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 1781E+02 (     )

9  FATSTD= 0 8039E+01 (dB)            10 FASTD= 0 1078E+02 (dB)

11 SFAMEAN= 0 2056E+05 (-----)        12 SFASTD= 0 4484E+06 (  --   )

13 LCR= 0 1002E+01 (-----)            14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1257E+04 (-----)

16 SFMEAN= 0 4299E+05 (-----)

17 SFSTD= 0 4484E+06 (-----)          18 FSTD= 0 9414E+01 (dB)

19 FMEAN= 0 3613E+02 (dB)             20 DFMEAN= 0 6392E+01 (dB)

21 SDFMEAN= 0 2091E+01 (-----)        22 NMEAN= - 9557E+02 (dBm)

23 NSTD= 0 9414E+01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                Run 14
SCENARIO  NO MATCHING NETWORK
          RESIDENTIAL AREA
          FREQUENCY, 50MHz
          10" MONOPOLE ANTENNA, 1 4 in DIA
          RECEIVER   fo =5, rn =100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                       INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 5000E+02 (MHZ)              2  B  0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)              4  TM  0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1371E-02 (OHMS)              7  RAR  0 7100E+00 (OHMS)
8  XAR= - 6000E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)             10 XMR  0 0000E+00 (OHMS)
11 A  0 1000E+01 (-----)               12 RSR  0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)              14 RN  0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)              16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)            18 IMZOR= - 3623E+00 (OHMS)
19 ALPHAR= 0 1228E-01 (NEPERS/METER)   20 BETAR= 0 1590E+01 (NEPERS/METER)
21 DR  0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2544E+02 (dB)             23 DUFAT= 0 1231E+02 (dB)
24 DLFAT= 0 7016E+01 (dB)              25 FALSTD  0 3934E+01 (dB)

                       CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)              2  K= 0 1380E-22 (J/DEG K)

                       DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                2  ZOUT= (0 7114E+00 ,  - 6000E+03) (OHMS)

3  ZOR= (0 5000E+02 , - 3623E+00) (OHMS)

4  REFLR= (0 9848E+00 , - 1653E+00) (-----)

5  GAMMAR= (0 1228E-01 , 0 1590E+01) (NEPERS/METER)

6  YS= (0 2610E-02 , 0 5574E-02) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)   8  FR= 0 1781E+02 (     )

9  FATSTD= 0 7650E+01 (dB)            10 FASTD  0 8603E+01 (dB)

11 SFAMEAN= 0 2488E+04 (-----)        12 SFASTD= 0 1759E+05 (     )

13 LCR= 0 1002E+01 (-----)            14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1257E+04 (-----)

16 SFMEAN= 0 2492E+05 (-----)

17 SFSTD= 0 1752E+05 (-----)          18 FSTD= 0 2753E+01 (dB)

19 FMEAN= 0 4309E+02 (dB)             20 DFMEAN= 0 1765E+02 (dB)

21 SDFMEAN= 0 1001E+02 (-----)        22 NMEAN= - 8861E+02 (dBm)

23 NSTD= 0 2753E+01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 15

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 50MHZ
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES TABLE 1

FREQUENCY
1 FMHZ= 0 5000E+02 (MHZ) 2 B= 0 1200E+05 (HZ)

TEMPERATURE
3 TC 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1371E-02 (OHMS) 7 RAR 0 7100E+00 (OHMS)
8 XAR= - 6000E+03 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 3623E+00 (OHMS)
19 ALPHAR= 0 1228E-01 (NEPERS/METER) 20 BETAR= 0 1590E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2014E+02 (dB) 23 DUFAT= 0 5492E+01 (dB)
24 DLFAT= 0 1848E+01 (dB) 25 FALSTD= 0 3208E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 7114E+00 , 5000E+[illegible]) (OHMS)

3 ZOR= (0 5000E+02 , - 3623E+00) (OHMS)

4 REFLR= (0 9848E+00 , - 1653E+00) (-----)

5 GAMMAR= (0 1228E-01 , 0 1590E+01) (NEPERS/METER)

6 YS= (0 2610E-02 , 0 5574E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR 0 1[illegible]E+0[illegible]

9 FATSTD= 0 2993E+01 (dB) 10 FASTD= 0 43[illegible]E+01 (dB)

11 SFAMEAN= 0 1720E+03 (-----) 12 SFASTD 0 22[illegible]

13 LCR= 0 1002E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1257E+04 (-----)

16 SFMEAN= 0 2260E+05 (-----)

17 SFSTD= 0 2291E+03 (-----) 18 FSTD= 0 4402E-01 (dB)

19 FMEAN= 0 4354E+02 (dB) 20 DFMEAN= 0 2340E+02 (dB)

21 SDFMEAN= 0 1314E+03 (-----) 22 NMEAN= - 8816E+02 (dBm)

23 NSTD= 0 4402E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 28

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 7000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSID= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 8536E-04 , 0 1746E-01) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 8268E+03 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1937E+03 (-----)

16 SFMEAN= 0 1619E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 6989E-01 (dB)

19 FMEAN= 0 5209E+02 (dB) 20 DFMEAN= 0 2581E+02 (dB)

21 SDFMEAN= 0 1477E+03 (-----) 22 NMEAN= - 7961E+02 (dBm)

23 NSTD= 0 6989E-01 (dB)

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 27
SCENARIO: NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1.4 in  DIA.
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                      INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0.3000E+02 (MHZ)              2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)              4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1062E-02 (OHMS)              7  RAR= 0.2556E+00 (OHMS)
8  XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0.0000E+00 (OHMS)             10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)               12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)              14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)              16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)            18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)   20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.6000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)             23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)              25 FALSTD= 0.4070E+01 (dB)

                      CONSTANTS, TABLE 2

1  TO= 0.2880E+03 (DEG K)              2  K= 0.1380E-22 (J/DEG K)

                      DERIVED  VARIABLES, TABLE 3

1  W= -.1317E+03 (dBm)               2  ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3  ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4  REFLR= (0.9941E+00 , -.9965E-01) (-----)

5  GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6  YS= (0.5099E-04 , 0.1435E-01) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)  8  FR= 0.1189E+04 (-----)

9  FATSTD= 0.4379E+01 (dB)             10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)         12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)             14 LMR= 0.1000E+01 (-----)

15 LNR= 0.1352E+03 (-----)

16 SFMEAN= 0.1626E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)           18 FSTD= 0.6962E-01 (dB)

19 FMEAN= 0.5211E+02 (dB)              20 DFMEAN= 0.2583E+02 (dB)

21 SDFMEAN= 0.1483E+03 (-----)         22 NMEAN= -.7959E+02 (dBm)

23 NSTD= 0.6962E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 26

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE.

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 5000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 2962E-04 , 0 1164E-01) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 1809E+04 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 8930E+02 (-----)

16 SFMEAN= 0 1633E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 6931E-01 (dB)

19 FMEAN= 0 5213E+02 (dB) 20 DFMEAN= 0 2585E+02 (dB)

21 SDFMEAN= 0 1490E+03 (-----) 22 NMEAN= - 7957E+02 (dBm)

23 NSTD= 0 6931E-01 (dB)

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 25
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1.4 in. DIA
          RECEIVER:  fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                      INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0.3000E+02 (MHZ)               2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)               4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1062E-02 (OHMS)               7  RAR= 0.2556E+00 (OHMS)
8  XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0.0000E+00 (OHMS)              10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)                12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)               14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)               16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)             18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)    20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.4000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)              23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)               25 FALSTD= 0.4070E+01 (dB)

                      CONSTANTS, TABLE 2

1  TO= 0.2880E+03 (DEG K)               2  K= 0.1380E-22 (J/DEG K)

                      DERIVED  VARIABLES, TABLE 3

1  W= -.1317E+03 (dBm)                2  ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3  ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4  REFLR= (0.9941E+00 , -.9965E-01) (-----)

5  GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6  YS= (0.1644E-04 , 0.9210E-02) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)  8  FR= 0.2950E+04 (-----)

9  FATSTD= 0.4379E+01 (dB)            10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)        12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)            14 LMR= 0.1000E+01 (-----)

15 LNR= 0.5501E+02 (-----)

16 SFMEAN= 0.1640E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)          18 FSTD= 0.6900E-01 (dB)

19 FMEAN= 0.5215E+02 (dB)             20 DFMEAN= 0.2587E+02 (dB)

21 SDFMEAN= 0.1496E+03 (-----)        22 NMEAN= -.7955E+02 (dBm)

23 NSTD= 0.6900E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 24

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 3000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 8530E-05 , 0 6988E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 5263E+04 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 3094E+02 (-----)

16 SFMEAN= 0 1646E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 6876E-01 (dB)

19 FMEAN= 0 5216E+02 (dB) 20 DFMEAN= 0 2588E+02 (dB)

21 SDFMEAN= 0 1502E+03 (-----) 22 NMEAN= - 7954E+02 (dBm)

23 NSTD= 0 6876E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE — Run 23

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in. DIA
RECEIVER: f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ)
2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K)
4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS)
7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS)
10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)
12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)
14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)
16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)
18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)
20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.2000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)
23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)
25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K)
2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm)
2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.3998E-05 , 0.4910E-02) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS)
8 FR= 0.1061E+05 (-----)

9 FATSTD= 0.4379E+01 (dB)
10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)
12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)
14 LMR= 0.1000E+01 (-----)

15 LNR= 0.1535E+02 (-----)

16 SFMEAN= 0.1646E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)
18 FSTD= 0.6878E-01 (dB)

19 FMEAN= 0.5216E+02 (dB)
20 DFMEAN= 0.2588E+02 (dB)

21 SDFMEAN= 0.1501E+03 (-----)
22 NMEAN= -.7954E+02 (dBm)

23 NSTD= 0.6878E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 22

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in. DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0. 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0. 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0. 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W- - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0. 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 1556E-05 , 0 2928E-02) (MHOS)

7 YND= (0. 2000E-01 , 0. 0000E+00) (MHOS) 8 FR= 0 2626E+05 (-----)

9 FATSTD= 0. 4379E+01 (dB) 10 FASTD= 0 3979E+01 (dB)

11 SFAMEAN= 0. 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 6139E+01 (-----)

16 SFMEAN= 0. 1630E+06 (-----)

17 SFSTD= 0. 2606E+04 (-----) 18 FSTD= 0 6946E-01 (dB)

19 FMEAN= 0. 5212E+02 (dB) 20 DFMEAN= 0 2584E+02 (dB)

21 SDFMEAN= 0. 1487E+03 (-----) 22 NMEAN= - 7958E+02 (dBm)

23 NSTD= 0. 6946E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE   Run 21
SCENARIO: NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in. DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

```
FREQUENCY
1  FMHZ= 0.3000E+02 (MHZ)                    2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)                    4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1062E-02 (OHMS)                    7  RAR= 0.2556E+00 (OHMS)
8  XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0.0000E+00 (OHMS)                  10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)                    12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)                   14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)                   16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)                 18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)        20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.5000E-01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)                  23 DUFAT= 0.6710E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)                   25 FALSTD= 0.4070E+01 (dB)
```

CONSTANTS, TABLE 2

```
1  TO= 0.2880E+03 (DEG K)                   2  K= 0.1380E-22 (J/DEG K)
```

DERIVED VARIABLES, TABLE 3

```
1  W= -.1317E+03 (dBm)                      2  ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3  ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4  REFLR= (0.9941E+00 , -.9965E-01) (-----)

5  GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6  YS= (0.8140E-06 , 0.1959E-02) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)    8  FR= 0.4961E+05 (-----)

9  FATSTD= 0.4379E+01 (dB)                  10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)              12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)                  14 LMR= 0.1000E+01 (-----)

15 LNR= 0.3212E+01 (-----)

16 SFMEAN= 0.1611E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)                18 FSTD= 0.7025E-01 (dB)

19 FMEAN= 0.5207E+02 (dB)                   20 DFMEAN= 0.2579E+02 (dB)

21 SDFMEAN= 0.1470E+03 (-----)              22 NMEAN= -.7963E+02 (dBm)

23 NSTD= 0.7025E-01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                  Run 20
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                         INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 3000E+02 (MHZ)                  2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                  4  TM= 0 2880E+03 (DEG K)
5  TN  0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1062E-02 (OHMS)                  7  RAR= 0 2556E+00 (OHMS)
8  XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)                 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                   12 RSH= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                  14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                  16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)                18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)       20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 2000E-01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)                 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)                  25 FALSTD= 0 4070E+01 (dB)

                         CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                  2  K= 0 1380E-22 (J/DEG K)

                         DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                 2  ZOUT= (0 2567E+00 ,  - 1000E+04  (OHMS)

3  ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4  REFLR= (0 9941E+00 , - 9965E-01) (-----)

5  GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6  YS= (0 4642E-06 , 0 1383E-02) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 8659E+05 (-----)

9  FATSTD= 0 4379E+01 (dB)             10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----)         12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----)             14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1820E+01 (-----)

16 SFMEAN= 0 1594E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)           18 FSTD= 0 7103E-01 (dB)

19 FMEAN= 0 5202E+02 (dB)              20 DFMEAN= 0 2574E+02 (dB)

21 SDFMEAN= 0 1454E+03 (-----)         22 NMEAN= - 7968E+02 (dBm)

23 NSTD= 0 7103E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 19

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in DIA
RECEIVER: f_o=5, r_n=100 OHMS ,
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E-01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 3584E-06 , 0 1191E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 1120E+06 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1401E+01 (-----)

16 SFMEAN= 0 1586E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 7134E-01 (dB)

19 FMEAN= 0 5200E+02 (dB) 20 DFMEAN= 0 2572E+02 (dB)

21 SDFMEAN= 0 1447E+03 (-----) 22 NMEAN= - 7970E+02 (dBm)

23 NSTD= 0 7134E-01 (dB)

IV. C Effect of Transmission Line Length on System Noise

No Matching Networks, Rural Area, 30 MHz

Run 19	Transmission Line Length	= 0.01 m = 0.001λ
Run 20		= 0.02 m = 0.002λ
Run 21		= 0.05 m = 0.005λ
Run 22		= 0.1 m = 0.01λ
Run 23		= 0.2 m = 0.02λ
Run 24		= 0.3 m = 0.03λ
Run 25		= 0.4 m = 0.04λ
Run 26		= 0.5 m = 0.05λ
Run 27		= 0.6 m = 0.06λ
Run 28		= 0.7 m = 0.07λ
Run 29		= 0.8 m = 0.08λ
Run 30		= 0.9 m = 0.09λ
Run 31		= 1.0 m = 0.1λ
Run 32		= 2.0 m = 0.2λ
Run 33		= 3.0 m = 0.3λ
Run 34		= 4.0 m = 0.4λ
Run 35		= 5.0 m = 0.5λ
Run 36		= 6.0 m = 0.6λ
Run 37		= 7.0 m = 0.7λ
Run 38		= 8.0 m = 0.8λ
Run 39		= 9.0 m = 0.9λ
Run 40		= 10.0 m = 1.0λ
Run 41		= 20 m = 2.0λ
Run 42		= 50 m = 5.0λ
Run 43		= 100 m = 10.0λ

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 18
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 88MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER    fo =5,  rn =100 OHMS
          RG-58/U COAXIAL LINE, 10M LENGTH

                    INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 8800E+02 (MHZ)                2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1819E-02 (OHMS)                7  RAR= 0 2199E+01 (OHMS)
8  XAR= - 3409E+03 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)               10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)              18 IMZOR= - 2700E+00 (OHMS)
19 ALPHAR= 0 1646E-01 (NEPERS/METER)     20 BETAR= 0 2798E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 1334E+02 (dB)               23 DUFAT= 0 9140E+01 (dB)
24 DLFAT= 0 2760E+01 (dB)                25 FALSTD= 0 2794E+01 (dB)

                    CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                2  K= 0 1380E-22 (J/DEG K)

                    DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                   2  ZOUT= (0 2201E+01 , - 3409E+03) (OHMS)

3  ZOR= (0 5000E+02 , - 2700E+00) (OHMS)

4  REFLR= (0 9546E+00 , - 2862E+00) (-----)

5  GAMMAR= (0 1646E-01 , 0 2798E+01) (NEPERS/METER)

6  YS= (0 3380E-02 , -.2816E-02) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 1344E+02 (-----)

9  FATSTD= 0 4885E+01 (dB)               10 FASTD= 0 5628E+01 (dB)

11 SFAMEAN= 0 4993E+02 (-----)           12 SFASTD= 0 1043E+03 (-----)

13 LCR= 0 1001E+01 (-----)               14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1834E+03 (-----)

16 SFMEAN= 0 2515E+04 (-----)

17 SFSTD= 0 1043E+03 (-----)             18 FSTD= 0 1800E+00 (dB)

19 FMEAN= 0 3400E+02 (dB)                20 DFMEAN= 0 2066E+02 (dB)

21 SDFMEAN= 0 5036E+02 (-----)           22 NMEAN= - 9770E+02 (dBm)

23 NSTD= 0 1800E+00 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE — Run 17

SCENARIO NO MATCHING NETWORK
RESIDENTIAL AREA
FREQUENCY, 88MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 8800E+02 (MHZ)   2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K)   4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1819E-02 (OHMS)   7 RAR= 0 2199E+01 (OHMS)
8 XAR= - 3409E+03 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS)   10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)   12 RSP= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)   14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)   16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)   18 IMZOR= [illegible] 2700E+00 (OHMS)
19 ALPHAR= 0 1646E-01 (NEPERS/METER)   20 BETAR= 0 2798E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 1864E+02 (dB)   23 DUFAT= 0 1245E+0[illegible] (dB)
24 DLFAT= 0 5420E+01 (dB)   25 FALSTD= 0 30[illegible]0E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K)   2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)   2 ZOUT= (0 2201E+01 , - 3409E+03) (OHMS)

3 ZOR= (0 5000E+02 , - 2700E+00) (OHMS)

4 REFLR= (0 9546E+00 , - 2862E+00) (-----)

5 GAMMAR= (0 1646E-01 , 0 2798E+01) (NEPERS/METER)

6 YS= (0 3380E-02 , - 2816E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS)   8 FR= 0 1[illegible]4E+0[illegible] (-----)

9 FATSTD= 0 7173E+01 (dB)   10 FASTD= 0 [illegible]799E+01 (dB)

11 SFAMEAN= 0 3664E+03 (-----)   12 SFASTD= 0 1[illegible]00E+04 (-----)

13 LCR= 0 1001E+01 (-----)   14 LMR= 0 1000E+0[illegible] (-----)

15 LNR= 0 1834E+03 (-----)

16 SFMEAN= 0 2831E+04 (-----)

17 SFSTD= 0 1800E+04 (-----)   18 FSTD= 0 2531E+[illegible]1 (dB)

19 FMEAN= 0 3378E+02 (dB)   20 DFMEAN= 0 1514E+02 (dB)

21 SDFMEAN= 0 7727E+01 (-----)   22 NMEAN= - 9792E+02 (dBm)

23 NSTD= 0 2531E+01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 16

SCENARIO NO MATCHING NETWORK
BUSINESS AREA
FREQUENCY, 88MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE, 10M LENGTH

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 8800E+02 (MHZ)
2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K)
4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1819E-02 (OHMS)
7 RAR= 0 2199E+01 (OHMS)
8 XAR= - 3409E+03 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS)
10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)
12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)
14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)
16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)
18 IMZOR= - 2700E+00 (OHMS)
19 ALPHAR= 0 1646E-01 (NEPERS/METER)
20 BETAR= 0 2798E+01 (NEPERS/METER)
21 DR= 0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2294E+02 (dB)
23 DUFAT= 0 122?E+02 (dB)
24 DLFAT= - 9500E+01 (dB)
25 FALSTD= 0 8330E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K)
2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)
2 ZOUT= (0 2201E+01 , - 3409E+03) (OHMS)

3 ZOR= (0 5000E+02 , - 2700E+00) (OHMS)

4 REFLR= (0 9546E+00 , - 2862E+00) (-----)

5 GAMMAR= (0 1646E-01 , 0 2798E+01) (NEPERS/METER)

6 YS= (0 3380E-02 , - 2816E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS)
8 FR= 0 1344E+0? (-----)

9 FATSTD= 0 5222E+01 (dB)
10 FASTD= 0 98?2E+01 (dB)

11 SFAMEAN= 0 2551E+04 (-----)
12 SFASTD= 0 3298E+05 (-----)

13 LCR= 0 1001E+01 (-----)
14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1834E+03 (-----)

16 SFMEAN= 0 5016E+04 (-----)

17 SFSTD= 0 3298E+05 (-----)
18 FSTD= 0 8454E+01 (dB)

19 FMEAN= 0 2877E+02 (dB)
20 DFMEAN= 0 5837E+01 (dB)

21 SDFMEAN= 0 1966E+01 (-----)
22 NMEAN= - 1029E+03 (dBm)

23 NSTD= 0 8454E+01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 29

SCENARIO: NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER: f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0.2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0.0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 8000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0.2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.1410E-03 , 0.2114E-01) (MHOS)

7 YNO= (0.2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 6016E+03 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 2653E+03 (-----)

16 SFMEAN= 0 1614E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 7015E-01 (dB)

19 FMEAN= 0 5208E+02 (dB) 20 DFMEAN= 0 2579E+02 (dB)

21 SDFMEAN= 0.1472E+03 (-----) 22 NMEAN= - 7963E+02 (dBm)

23 NSTD= 0 7015E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 30

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ)   2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K)   4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS)   7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS)   10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)   12 RSR 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)   14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)   16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)   18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)   20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 9000E+00 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)   23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)   25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TG= 0 2880E+03 (DEG K)   2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm)   2 ZOUT= (0 2557E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 2332E-03 , 0 2565E-01) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS)   8 FR= 0 4546E+03 (-----)

9 FATSTD= 0 4379E+01 (dB)   10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----)   12 SFASTD= 0 2506E+04 (-----)

13 LCR= 0 1004E+01 (-----)   14 LMR= 0 1000E+01 (-----)

15 LNR= 0 3500E+03 (-----)

16 SFMEAN= 0 1609E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)   18 FSTD= 0 7036E-01 (dB)

19 FMEAN= 0 5206E+02 (dB)   20 DFMEAN= 0 2578E+02 (dB)

21 SDFMEAN= 0 1468E+03 (-----)   22 NMEAN= - 7964E+02 (dBm)

23 NSTD= 0 7036E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 31

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA.
RECEIVER: f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE.

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 1000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 3921E-03 , 0 3141E-01) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 3548E+03 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 4473E+03 (-----)

16 SFMEAN= 0 1605E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 7055E-01 (dB)

19 FMEAN= 0 5205E+02 (dB) 20 DFMEAN= 0 2577E+02 (dB)

21 SDFMEAN= 0 1464E+03 (-----) 22 NMEAN= - 7965E+02 (dBm)

23 NSTD= 0 7055E-01 (dB)

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                Run 32
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1 4 in. DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                    INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 3000E+02 (MHZ)                 2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                 4  TM= 0.2880E+03 (DEG K)
5  TN  0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1062E-02 (OHMS)                 7  RAR= 0 2556E+00 (OHMS)
8  XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)                10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                  12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)               18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)      20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 2000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)                23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)                 25 FALSTD= 0 4070E+01 (dB)

                    CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                 2  K= 0.1380E-22 (J/DEG K)

                    DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                  2  ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3  ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4  REFLR= (0 9941E+00 , - 9965E-01) (-----)

5  GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6  YS= (0 3172E-02 , - 4889E-01) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)  8  FR= 0.8933E+02 (-----)

9  FATSTD= 0 4379E+01 (dB)              10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)          12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----)              14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1758E+04 (-----)

16 SFMEAN= 0 1588E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)            18 FSTD= 0 7126E-01 (dB)

19 FMEAN= 0 5201E+02 (dB)               20 DFMEAN= 0 2573E+02 (dB)

21 SDFMEAN= 0 1449E+03 (-----)          22 NMEAN= - 7969E+02 (dBm)

23 NSTD= 0 7126E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 33

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ)   2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K)   4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS)   7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS)   10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)   12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)   14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)   16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)   18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)   20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.3000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)   23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)   25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K)   2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm)   2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.6514E-03 , -.4665E-02) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8 FR= 0.6584E+02 (-----)

9 FATSTD= 0.4379E+01 (dB)   10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)   12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)   14 LMR= 0.1000E+01 (-----)

15 LNR= 0.2402E+04 (-----)

16 SFMEAN= 0.1599E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)   18 FSTD= 0.7079E-01 (dB)

19 FMEAN= 0.5204E+02 (dB)   20 DFMEAN= 0.2575E+02 (dB)

21 SDFMEAN= 0.1459E+03 (-----)   22 NMEAN= -.7966E+02 (dBm)

23 NSTD= 0.7079E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 34

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ)   2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K)   4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS)   7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS)   10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)   12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)   14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)   16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)   18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)   20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.4000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)   23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)   25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K)   2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm)   2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.1195E-02 , 0.1766E-01) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8 FR= 0.6071E+02 (-----)

9 FATSTD= 0.4379E+01 (dB)   10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)   12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)   14 LMR= 0.1000E+01 (-----)

15 LNR= 0.2648E+04 (-----)

16 SFMEAN= 0.1625E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)   18 FSTD= 0.6964E-01 (dB)

19 FMEAN= 0.5211E+02 (dB)   20 DFMEAN= 0.2583E+02 (dB)

21 SDFMEAN= 0.1483E+03 (-----)   22 NMEAN= -.7959E+02 (dBm)

23 NSTD= 0.6964E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE   Run 35
SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in. DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE.

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ)   2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K)   4 TM= 0.2880E+03 (DEG K)
5 TN 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS)   7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS)   10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)   12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)   14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)   16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)   18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)   20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.5000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)   23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)   25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K)   2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm)   2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.7066E-01 , -.1540E+00) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8 FR= 0.4223E+02 (-----)

9 FATSTD= 0.4379E+01 (dB)   10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)   12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)   14 LMR= 0.1000E+01 (-----)

15 LNR= 0.3797E+04 (-----)

16 SFMEAN= 0.1621E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)   18 FSTD= 0.6983E-01 (dB)

19 FMEAN= 0.5210E+02 (dB)   20 DFMEAN= 0.2581E+02 (dB)

21 SDFMEAN= 0.1479E+03 (-----)   22 NMEAN= -.7961E+02 (dBm)

23 NSTD= 0.6983E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 36

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in. DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ) 2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K) 4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS) 7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS) 10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----) 12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----) 14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS) 16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS) 18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER) 20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.6000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB) 23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB) 25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K) 2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm) 2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.1600E-02 , -.1110E-01) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS) 8 FR= 0.3389E+02 (-----)

9 FATSTD= 0.4379E+01 (dB) 10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----) 12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----) 14 LMR= 0.1[illegible]+01 (-----)

15 LNR= 0.4745E+04 (-----)

16 SFMEAN= 0.1626E+06 (-----)

17 SFSTD= 0.2606E+04 (-----) 18 FSTD= 0.6962E-01 (dB)

19 FMEAN= 0.5211E+02 (dB) 20 DFMEAN= 0.2583E+02 (dB)

21 SDFMEAN= 0.1483E+03 (-----) 22 NMEAN= -.7959E+02 (dBm)

NSTD= 0.6962E-01 (dB)

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 37

SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K) 4 TM= 0.2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0.7000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.1540E-02 , 0.9495E-02) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS) 8 FR= 0.3300E+02 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----) 12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0.1000E+01 (-----)

15 LNR= 0 4958E+04 (-----)

16 SFMEAN= 0.1654E+06 (-----)

17 SFSTD= 0.2606E+04 (-----) 18 FSTD= 0.6843E-01 (dB)

19 FMEAN= 0.5218E+02 (dB) 20 DFMEAN= 0.2590E+02 (dB)

21 SDFMEAN= 0.1509E+03 (-----) 22 NMEAN= -.7952E+02 (dBm)

23 NSTD= C 6843E-01 (dB)

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PROGRAM SONF   SYSTEM OPERATING NOISE FIGURE                   Run 38
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                         INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 3000E+02 (MHZ)                  2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                  4  TM  0 2880E+03 (DEG K)
5  TN  0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1062E-02 (OHMS)                  7  RAR= 0 2556E+00 (OHMS)
8  XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)                 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (------)                  12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (------)                 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                  16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)                18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)       20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 8000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)                 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)                  25 FALSTD= 0 4070E+01 (dB)

                         CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                  2  K= 0 1380E-22 (J/DEG K)

                    DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                2  ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3  ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4  REFLR= (0 9941E+00 , - 9965E-01) (------)

5  GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6  YS= (0 4258E-01 , 0 9652E-01) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)   8  FR= 0 2811E+02 (------)

9  FATSTD= 0 4379E+01 (dB)            10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (------)       12 SFASTD= 0 2606E+04 (------)

13 LCR= 0 1004E+01 (------)           14 LMR= 0 1000E+01 (------)

15 LNR= 0 5845E+04 (------)

16 SFMEAN= 0 1661E+06 (------)

17 SFSTD= 0 2606E+04 (------)         18 FSTD= 0 6815E-01 (dB)

19 FMEAN= 0 5220E+02 (dB)             20 DFMEAN= 0 2592E+02 (dB)

21 SDFMEAN= 0 1515E+03 (------)       22 NMEAN= - 7950E+02 (dBm)

23 NSTD= 0 6815E-01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                Run 39
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1.4 in  DIA
          RECEIVER   fo=5, rn=100 OHMS
          RG-58/U COAXIAL LINE,

                       INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0.3000E+02 (MHZ)                 2  B= 0.1700E+05 (HZ)

TEMPERATURE
3  TC= 0.2880E+03 (DEG K)                 4  TM= 0.2880E+03 (DEG K)
5  TN= 0.2880E+03 (DEG K)

ANTENNA
6  RCR= 0.1062E-02 (OHMS)                 7  RAR= 0.2556E+00 (OHMS)
8  XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0.0000E+00 (OHMS)               10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----)                 12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----)                14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS)                16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS)              18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER)     20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.9000E+01 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB)               23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB)                25 FALSTD= 0.4070E+01 (dB)

                        CONSTANTS, TABLE 2

1  TO= 0.2880E+03 (DEG K)                2  K= 0.1380E-22 (J/DEG K)

                     DERIVED  VARIABLES, TABLE 3

1  W= -.1317E+03 (dBm)                 2  ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3  ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4  REFLR= (0.9941E+00 , -.9965E-01) (-----)

5  GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6  YS= (0.3595E-02 , -.1981E-01) (MHOS)

7  YNO= (0.2000E-01 , 0.0000E+00) (MHOS)   8  FR= 0.2343E+02 (-----)

9  FATSTD= 0.4379E+01 (dB)             10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----)         12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----)             14 LMR= 0.1000E+01 (-----)

15 LNR= 0.7008E+04 (-----)

16 SFMEAN= 0.1660E+06 (-----)

17 SFSTD= 0.2606E+04 (-----)           18 FSTD= 0.6818E-01 (dB)

19 FMEAN= 0.5220E+02 (dB)              20 DFMEAN= 0.2592E+02 (dB)

21 SDFMEAN= 0.1514E+03 (-----)         22 NMEAN= -.7950E+02 (dBm)

23 NSTD= 0.6818E-01 (dB)
```

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 40
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo =5, rn =100 OHMS
          RG-58/U COAXIAL LINE.

                        INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 3000E+02 (MHZ)                2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                4  TM  0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1062E-02 (OHMS)                7  RAR= 0 2556E+00 (OHMS)
8  XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9  RMR= 0 0000E+00 (OHMS)                10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)              18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)     20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR  0 1000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)               23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)                25 FALSTD= 0 4070E+01 (dB)

                        CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                2  K= 0 1380E-22 (J/DEG K)

                     DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                 2  ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3  ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4  REFLR= (0 9941E+00 , - 9965E-01) (-----)

5  GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6  YS= (0 1913E-02 , 0 3321E-02) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 2271E+02 (-----)

9  FATSTD= 0 4379E+01 (dB)             10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----)         12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----)             14 LMR= 0 1000E+01 (-----)

15 LNR= 0 7348E+04 (-----)

16 SFMEAN= 0 1686E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)           18 FSTD= 0 6712E-01 (dB)

19 FMEAN= 0 5227E+02 (dB)              20 DFMEAN= 0 2599E+02 (dB)

21 SDFMEAN= 0 1538E+03 (-----)         22 NMEAN= - 7943E+02 (dBm)

23 NSTD= 0 6712E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 41
SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1 4 in DIA
RECEIVER f_o =5, r_n =100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0 3000E+02 (MHZ) 2 B= 0 1700E+05 (HZ)

TEMPERATURE
3 TC= 0 2880E+03 (DEG K) 4 TM= 0 2880E+03 (DEG K)
5 TN= 0 2880E+03 (DEG K)

ANTENNA
6 RCR= 0 1062E-02 (OHMS) 7 RAR= 0 2556E+00 (OHMS)
8 XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0 0000E+00 (OHMS) 10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----) 12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----) 14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS) 16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS) 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER) 20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 2000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB) 23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB) 25 FALSTD= 0 4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0 2880E+03 (DEG K) 2 K= 0 1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= - 1317E+03 (dBm) 2 ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3 ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4 REFLR= (0 9941E+00 , - 9965E-01) (-----)

5 GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6 YS= (0 3988E-02 , 0 5580E-02) (MHOS)

7 YNO= (0 2000E-01 , 0 0000E+00) (MHOS) 8 FR= 0 1224E+02 (-----)

9 FATSTD= 0 4379E+01 (dB) 10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----) 12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----) 14 LMR= 0 1000E+01 (-----)

15 LNR= 0 1499E+05 (-----)

16 SFMEAN= 0 1853E+06 (-----)

17 SFSTD= 0 2606E+04 (-----) 18 FSTD= 0 6109E-01 (dB)

19 FMEAN= 0 5268E+02 (dB) 20 DFMEAN= 0 2639E+02 (dB)

21 SDFMEAN= 0 1690E+03 (-----) 22 NMEAN= - 7902E+02 (dBm)

23 NSTD= 0 6109E-01 (dB)

```
PROGRAM SONF  SYSTEM OPERATING NOISE FIGURE                    Run 42
SCENARIO  NO MATCHING NETWORK
          RURAL AREA
          FREQUENCY, 30MHz
          10" MONOPOLE ANTENNA, 1 4 in  DIA
          RECEIVER   fo =5, rn =100 OHMS
          RG-58/U COAXIAL LINE.

                         INPUT VARIABLES, TABLE 1

FREQUENCY
1  FMHZ= 0 3000E+02 (MHZ)                    2  B= 0 1700E+05 (HZ)

TEMPERATURE
3  TC= 0 2880E+03 (DEG K)                    4  TM= 0 2880E+03 (DEG K)
5  TN= 0 2880E+03 (DEG K)

ANTENNA
6  RCR= 0 1062E-02 (OHMS)                    7  RAR= 0 2556E+00 (OHMS)
8  XAR= - 1000E+04 (OHMS)

MATCHING NETWORK
 9  RMR= 0 0000E+00 (OHMS)                  10 XMR= 0 0000E+00 (OHMS)
11 A= 0 1000E+01 (-----)                    12 RSR= 0 0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0 5030E+01 (-----)                   14 RN= 0 1000E+03 (OHMS)
15 GNO= 0 2000E-01 (MHOS)                   16 BNO= 0 0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0 5000E+02 (OHMS)                 18 IMZOR= - 4713E+00 (OHMS)
19 ALPHAR= 0 9442E-02 (NEPERS/METER)        20 BETAR= 0 9540E+00 (NEPERS/METER)
21 DR= 0 5000E+02 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0 2628E+02 (dB)                  23 DUFAT= 0 6910E+01 (dB)
24 DLFAT= 0 4180E+01 (dB)                   25 FALSTD= 0 4070E+01 (dB)

                         CONSTANTS, TABLE 2

1  TO= 0 2880E+03 (DEG K)                   2  K= 0 1380E-22 (J/DEG K)

                     DERIVED  VARIABLES, TABLE 3

1  W= - 1317E+03 (dBm)                  2  ZOUT= (0 2567E+00 , - 1000E+04) (OHMS)

3  ZOR= (0 5000E+02 , - 4713E+00) (OHMS)

4  REFLR= (0 9941E+00 , - 9965E-01) (-----)

5  GAMMAR= (0 9442E-02 , 0 9540E+00) (NEPERS/METER)

6  YS= (0 1207E-01 , 0 1070E-01) (MHOS)

7  YNO= (0 2000E-01 , 0 0000E+00) (MHOS)  8  FR= 0 6498E+01 (-----)

9  FATSTD= 0 4379E+01 (dB)              10 FASTD= 0 5979E+01 (dB)

11 SFAMEAN= 0 1096E+04 (-----)          12 SFASTD= 0 2606E+04 (-----)

13 LCR= 0 1004E+01 (-----)              14 LMR= 0 1000E+01 (-----)

15 LNR= 0 4246E+05 (-----)

16 SFMEAN= 0 2782E+06 (-----)

17 SFSTD= 0 2606E+04 (-----)            18 FSTD= 0 4068E-01 (dB)

19 FMEAN= 0 5444E+02 (dB)               20 DFMEAN= 0 2816E+02 (dB)

21 SDFMEAN= 0 2538E+03 (-----)          22 NMEAN= - 7726E+02 (dBm)

23 NSTD= 0 4068E-01 (dB)
```

PROGRAM SONF SYSTEM OPERATING NOISE FIGURE Run 43
SCENARIO NO MATCHING NETWORK
RURAL AREA
FREQUENCY, 30MHz
10" MONOPOLE ANTENNA, 1.4 in DIA
RECEIVER f_o=5, r_n=100 OHMS
RG-58/U COAXIAL LINE,

INPUT VARIABLES, TABLE 1

FREQUENCY
1 FMHZ= 0.3000E+02 (MHZ) 2 B= 0.1700E+05 (HZ)

TEMPERATURE
3 TC= 0.2880E+03 (DEG K) 4 TM= 0.2880E+03 (DEG K)
5 TN= 0.2880E+03 (DEG K)

ANTENNA
6 RCR= 0.1062E-02 (OHMS) 7 RAR= 0.2556E+00 (OHMS)
8 XAR= -.1000E+04 (OHMS)

MATCHING NETWORK
9 RMR= 0.0000E+00 (OHMS) 10 XMR= 0.0000E+00 (OHMS)
11 A= 0.1000E+01 (-----) 12 RSR= 0.0000E+00 (OHMS)

RECEIVER NOISE
13 FO= 0.5030E+01 (-----) 14 RN= 0.1000E+03 (OHMS)
15 GNO= 0.2000E-01 (MHOS) 16 BNO= 0.0000E+00 (MHOS)

TRANSMISSION LINE
17 REZOR= 0.5000E+02 (OHMS) 18 IMZOR= -.4713E+00 (OHMS)
19 ALPHAR= 0.9442E-02 (NEPERS/METER) 20 BETAR= 0.9540E+00 (NEPERS/METER)
21 DR= 0.1000E+03 (METERS)

ENVIRONMENTAL NOISE
22 FAMEAN= 0.2628E+02 (dB) 23 DUFAT= 0.6910E+01 (dB)
24 DLFAT= 0.4180E+01 (dB) 25 FALSTD= 0.4070E+01 (dB)

CONSTANTS, TABLE 2

1 TO= 0.2880E+03 (DEG K) 2 K= 0.1380E-22 (J/DEG K)

DERIVED VARIABLES, TABLE 3

1 W= -.1317E+03 (dBm) 2 ZOUT= (0.2567E+00 , -.1000E+04) (OHMS)

3 ZOR= (0.5000E+02 , -.4713E+00) (OHMS)

4 REFLR= (0.9941E+00 , -.9965E-01) (-----)

5 GAMMAR= (0.9442E-02 , 0.9540E+00) (NEPERS/METER)

6 YS= (0.2441E-01 , 0.5318E-02) (MHOS)

7 YNO= (0.2000E-01 , 0.0000E+00) (MHOS) 8 FR= 0.5225E+01 (-----)

9 FATSTD= 0.4379E+01 (dB) 10 FASTD= 0.5979E+01 (dB)

11 SFAMEAN= 0.1096E+04 (-----) 12 SFASTD= 0.2606E+04 (-----)

13 LCR= 0.1004E+01 (-----) 14 LMR= 0.1000E+01 (-----)

15 LNR= 0.1260E+06 (-----)

16 SFMEAN= 0.6623E+06 (-----)

17 SFSTD= 0.2606E+04 (-----) 18 FSTD= 0.1710E-01 (dB)

19 FMEAN= 0.5821E+02 (dB) 20 DFMEAN= 0.3193E+02 (dB)

21 SDFMEAN= 0.6041E+03 (-----) 22 NMEAN= -.7349E+02 (dBm)

23 NSTD= 0.1710E-01 (dB)

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